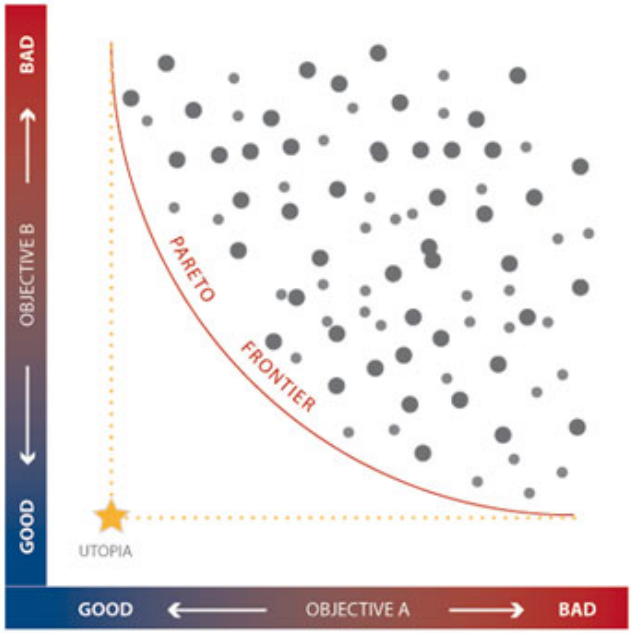

Multi-Objective Evolutionary Optimization

INRA
SCIENCE & IMPACT

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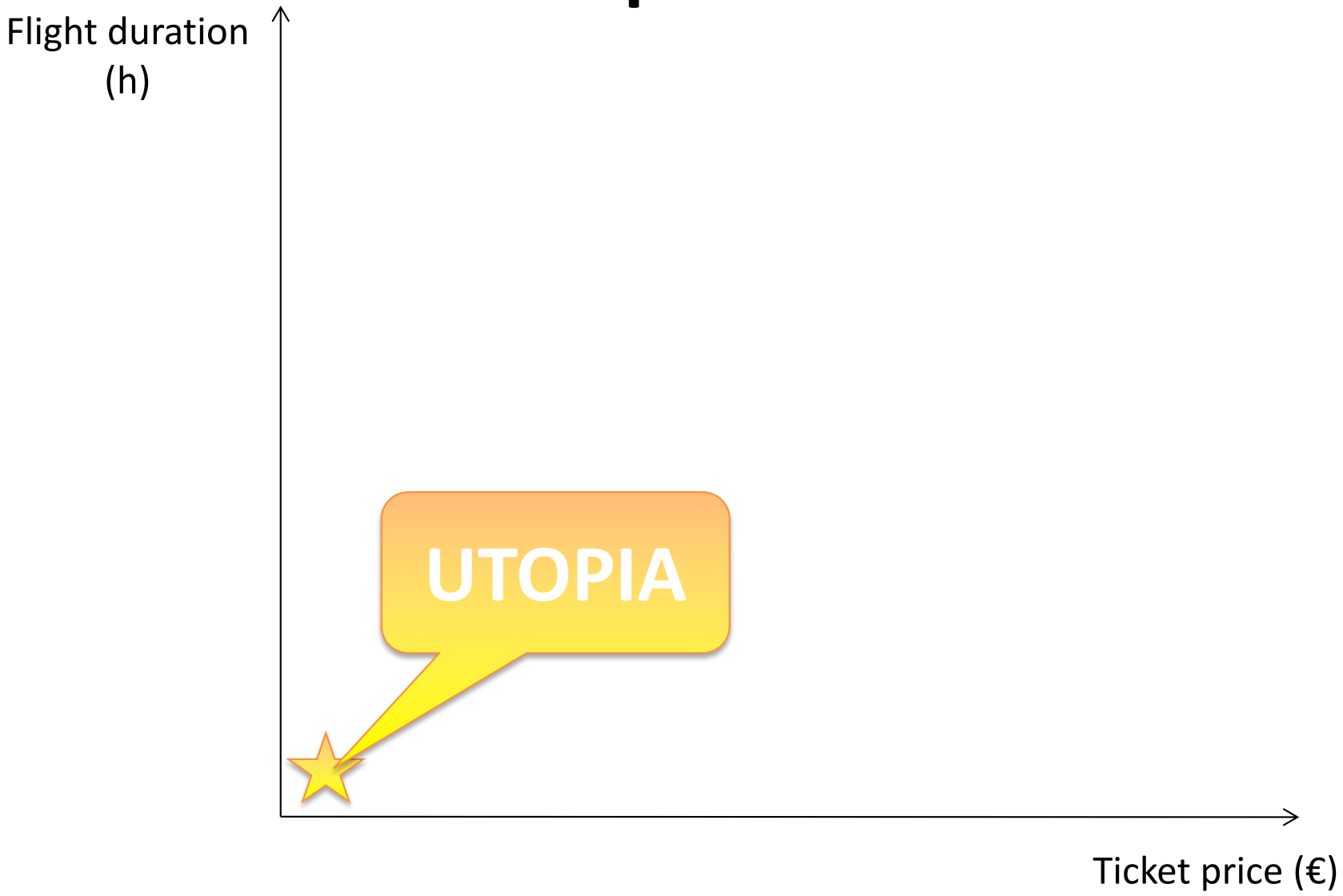
Outline

- Multi-objective problems
- Multi-objective optimization
- Real-world examples
- NSGA-II
- Other approaches
- **Many**-objective optimization…?

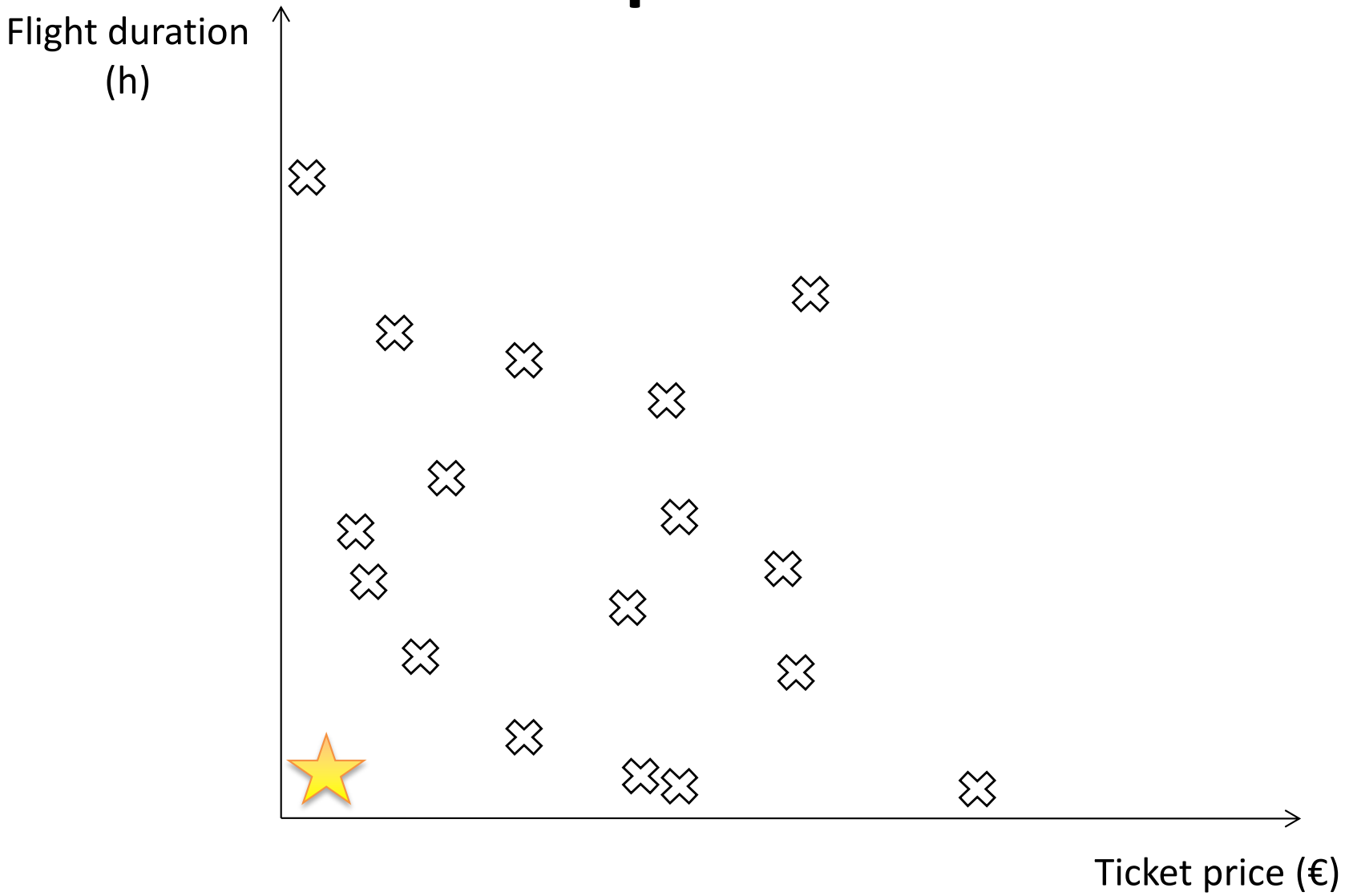
Multi-Objective Problems

Airplane tickets



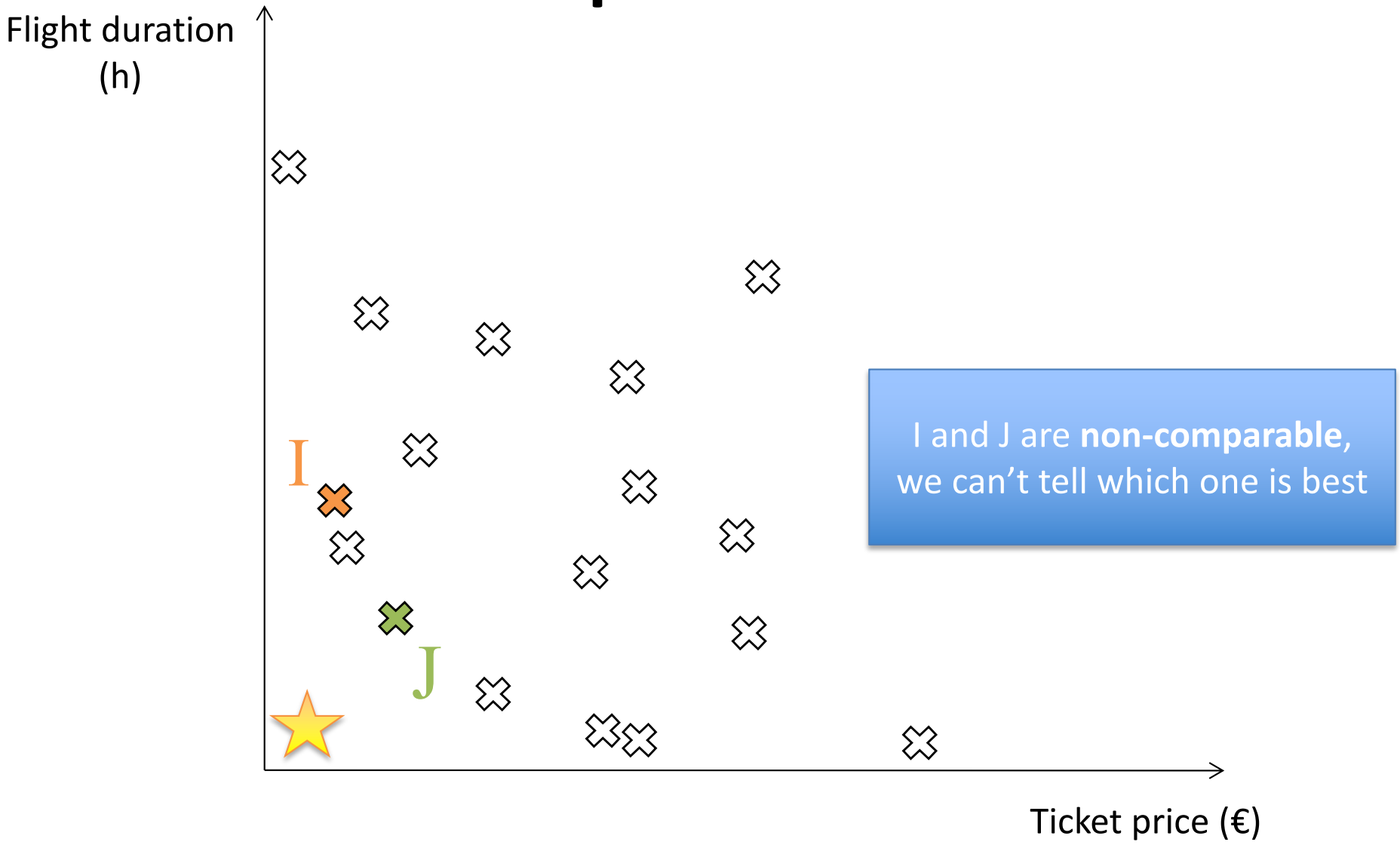
Multi-Objective Problems

Airplane tickets



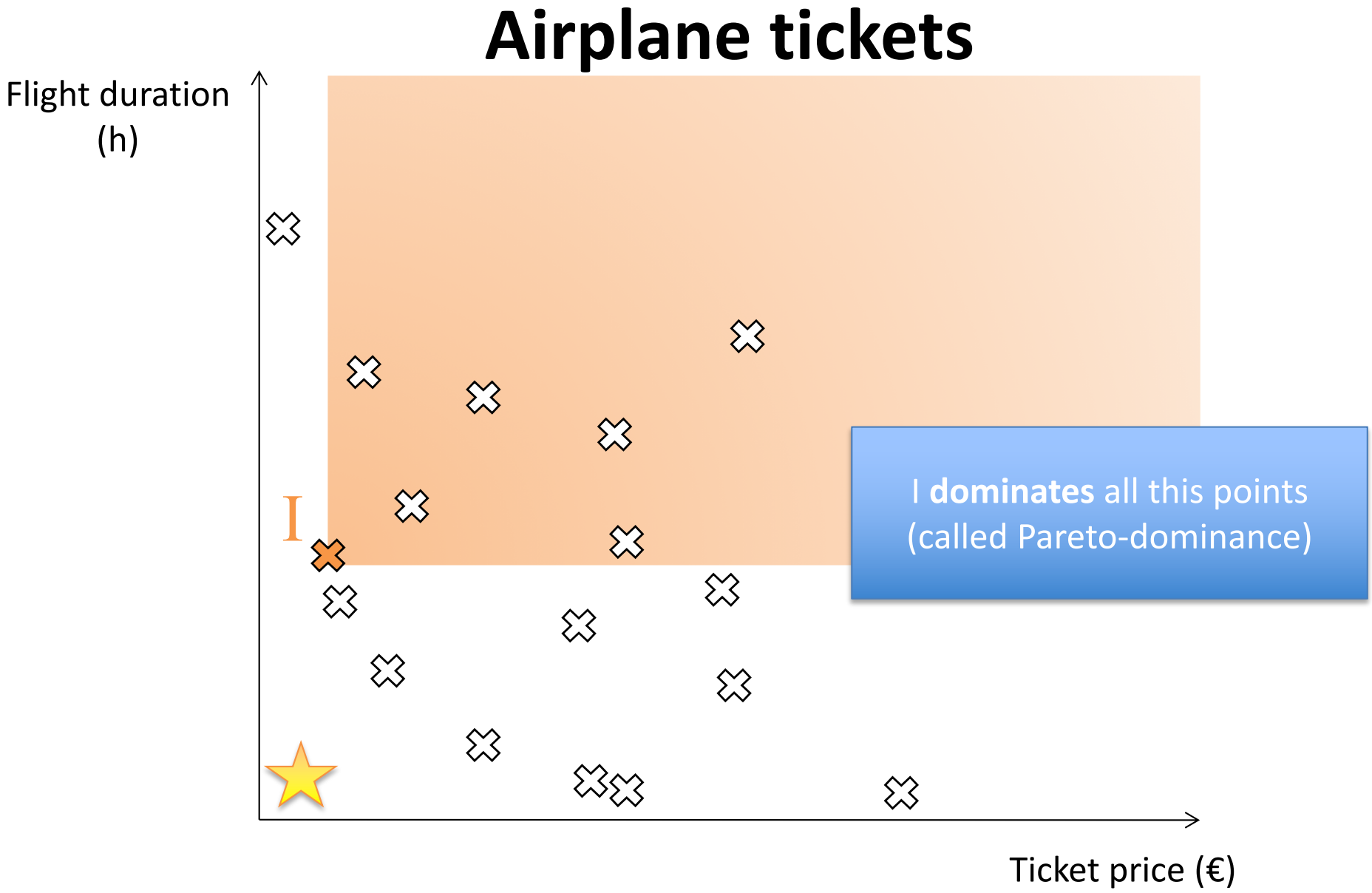
Multi-Objective Problems

Airplane tickets

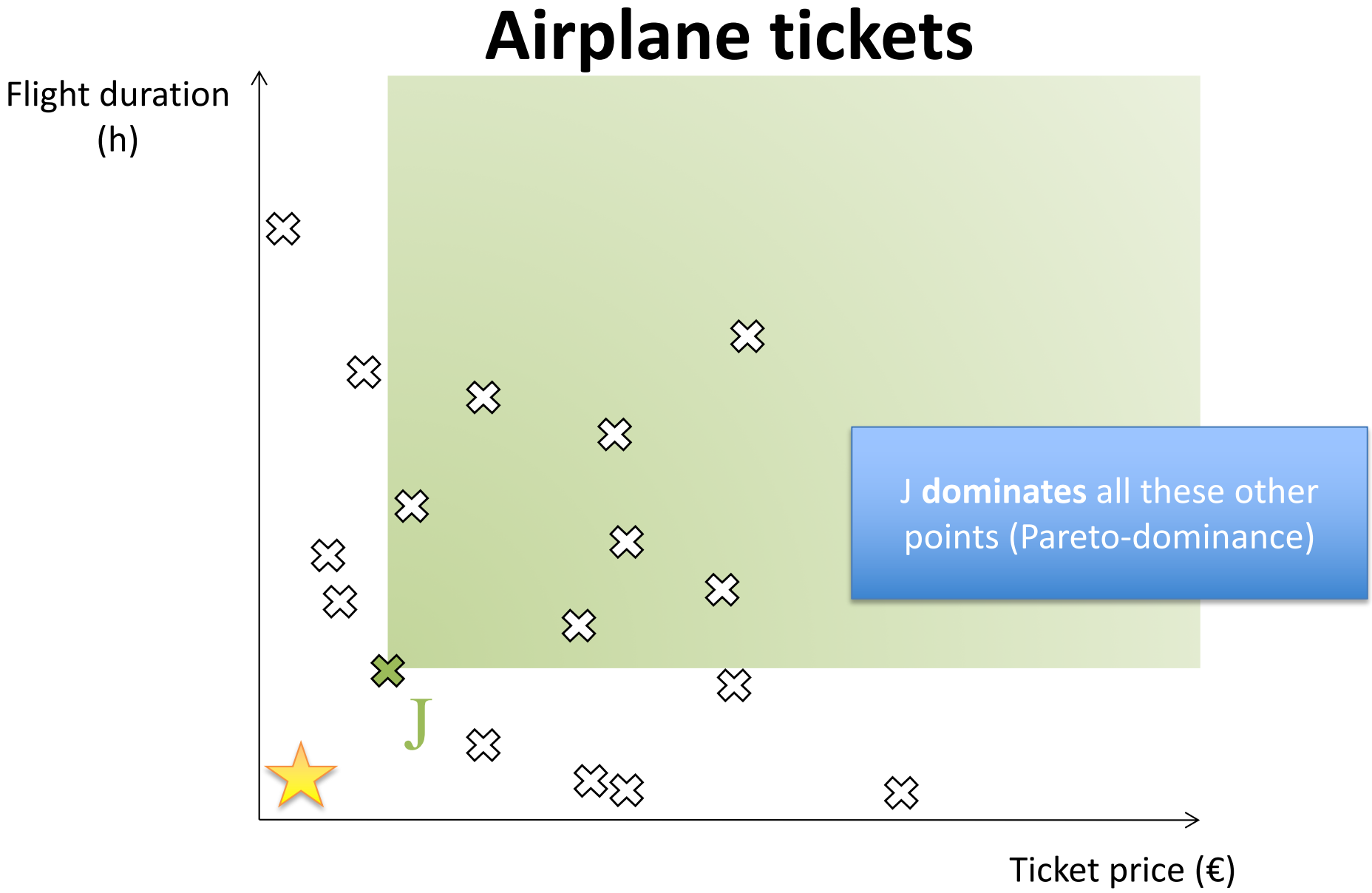


I and J are **non-comparable**, we can't tell which one is best

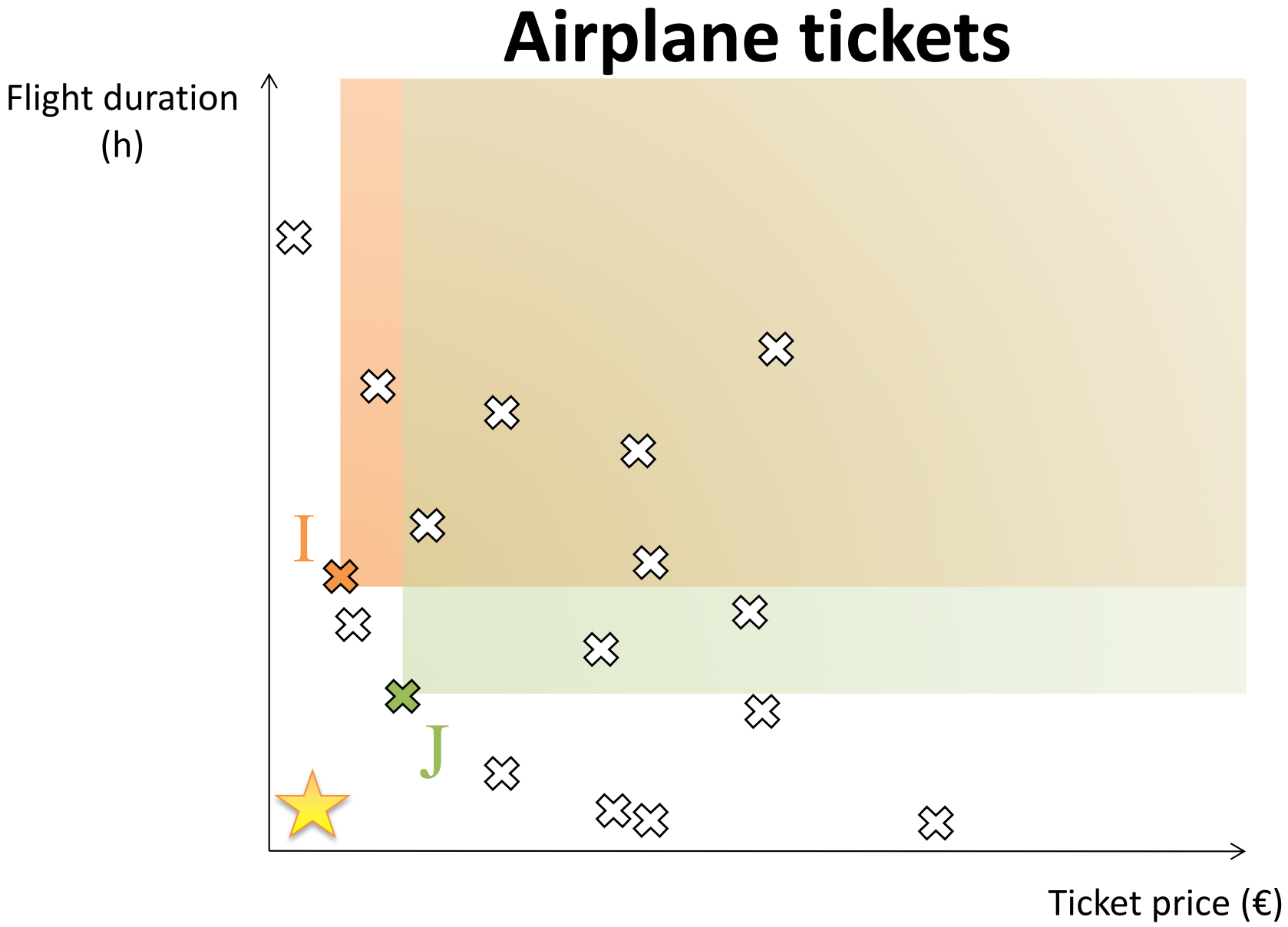
Multi-Objective Problems



Multi-Objective Problems

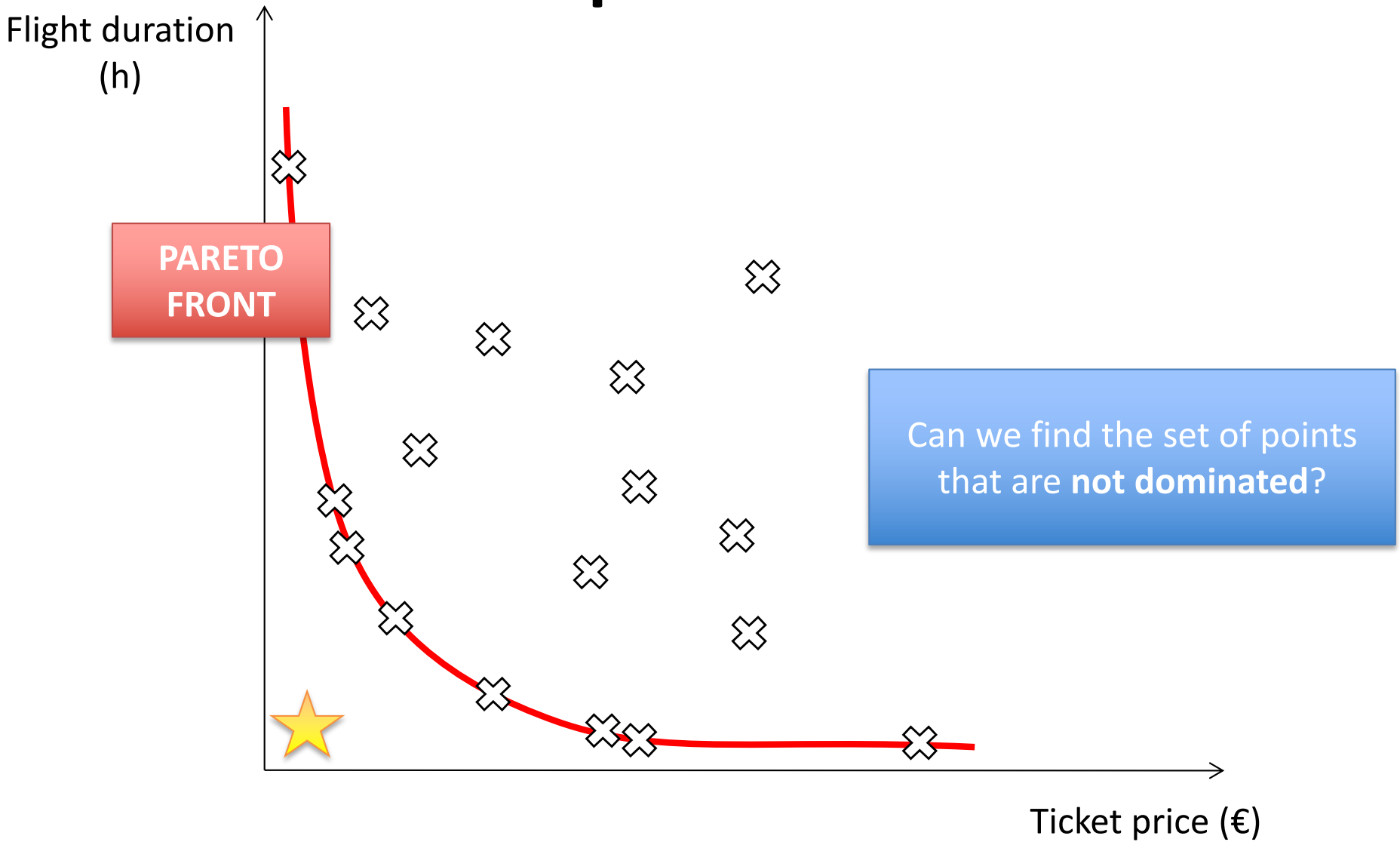


Multi-Objective Problems



Multi-Objective Problems

Airplane tickets



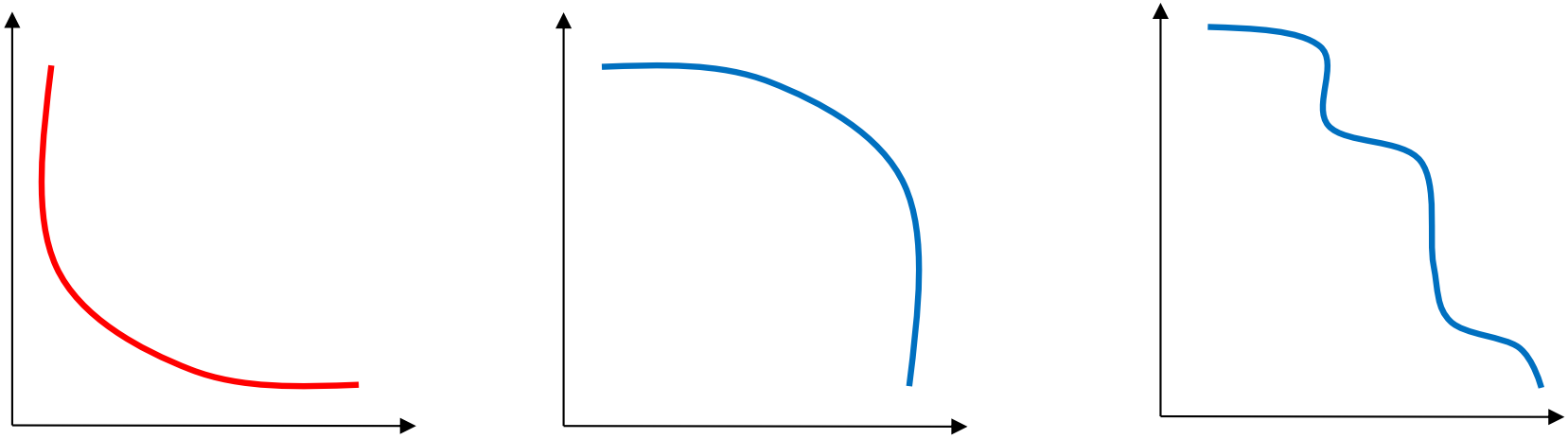
Multi-Objective Problems

- Pareto-optimality

  x' : solution $f_i(x)$: fitness

  $$f_i(x') \geq f_i(x) \; \forall \; x$$

- Pareto for *minimizing* or *maximizing*



Multi-Objective Problems

- Real-world problems are often MO
  - Often with A LOT of conflicting objectives
  - Plane tickets: seat position, airline, airport…
  - Production: energy, quality, price, …
  - Distribution: speed, cost, employment, …

Multi-Objective Optimization

- Single-objective optimization
  - Find ONE best solution

- Multi-objective optimization
  - Find THE PARETO FRONT (hard, maybe impossible)
  - Find as many non-dominated points as possible
  - Finding one point on the Pareto front is easy…
  - …but finding many is not!

Multi-Objective Optimization

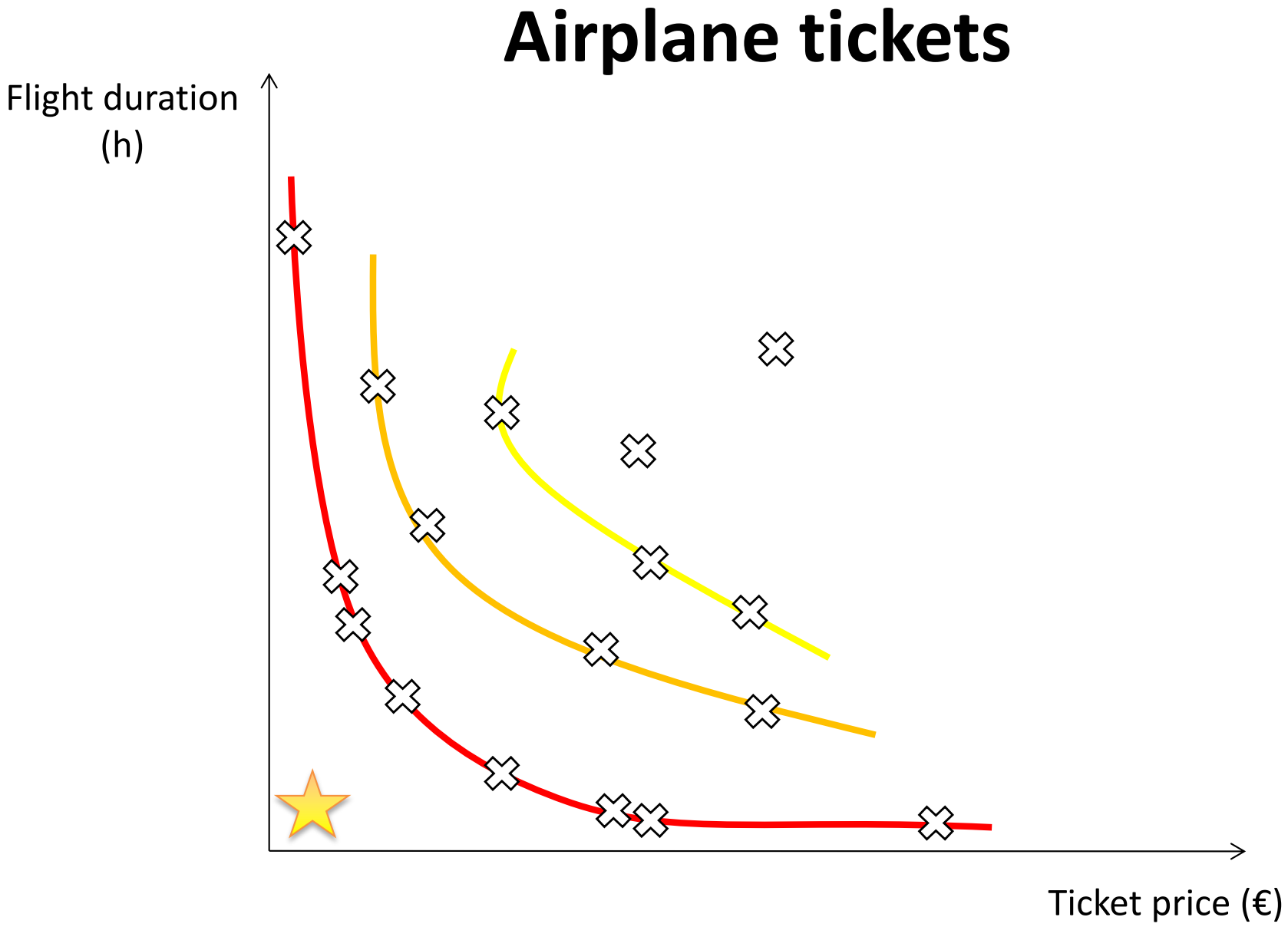
- Techniques to deal with MO
  - Assign weights to objectives, adjust weights
  - Some only work on (differential) equations
  - Multi-objective EAs (**state-of-the-art**)

- EAs are particularly suited
  - Population of solutions -> lots of points!
  - Black-box optimization -> easy to adopt!

Multi-Objective Optimization

- MOEAs (general idea)
  - Create population, evaluate
  - Create offspring
  - Find Pareto front
  - Remove individuals in Pareto front
  - Recompute Pareto front (iterate)
  - Obtain list of fronts
  - Kill individuals starting from worst fronts

Multi-Objective Problems



Example: Influence in Social Networks

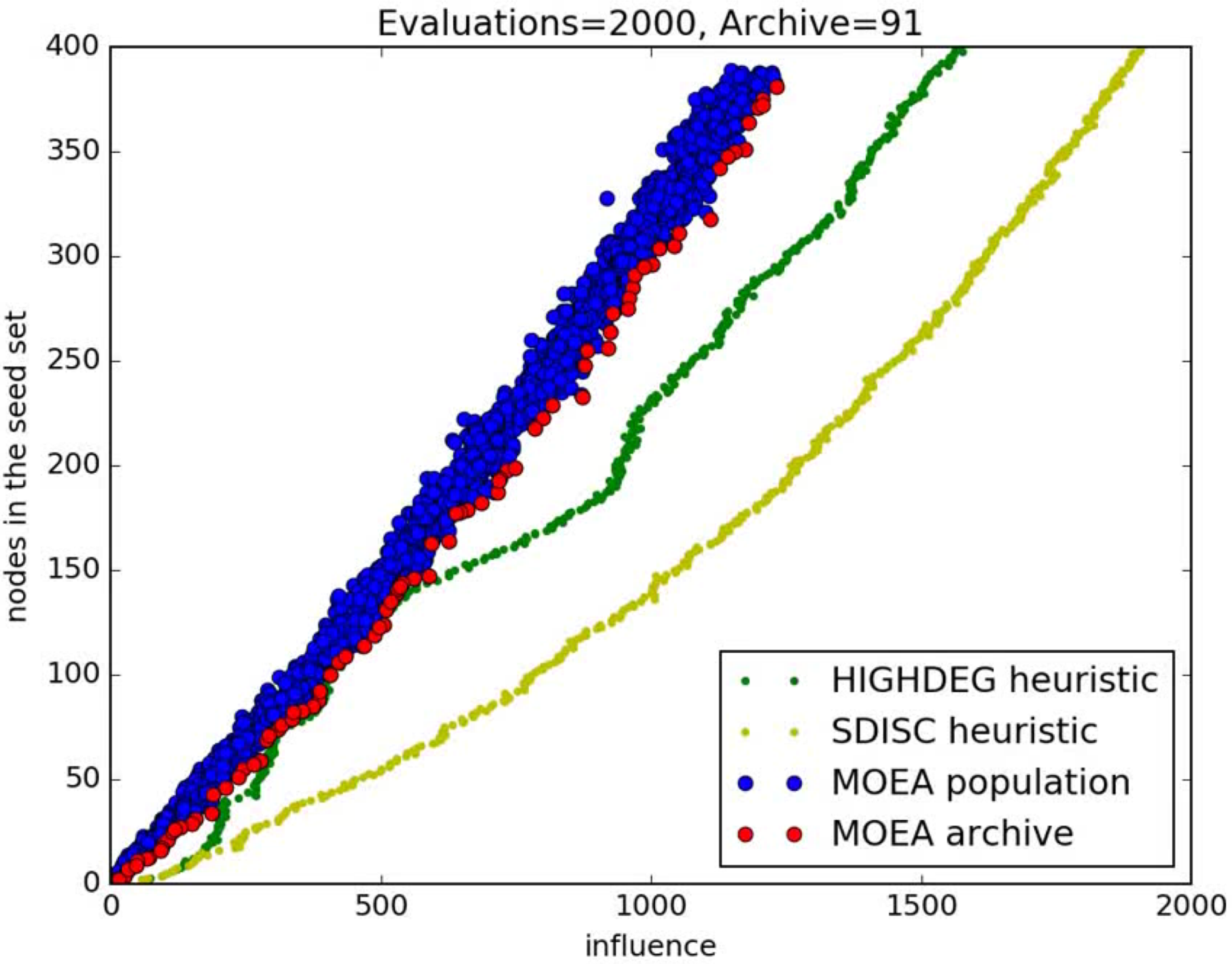
- Advertise products in social networks
  - Use influencers (lots of followers)
  - How to choose influencers? (following overlap)
  - Spend as little as possible

- Multi-objective problem
  - Minimize influencers
  - Maximize influence

Example: Influence in Social Networks

- Genome (candidate solution)
  - Set of nodes taken from a graph
  - Vector of integers of different size
  - String of bits (1=influencer, 0=not)

- Fitness function
  - (Max) influence spread in the network
  - (Min) number of nodes/influencers


Evaluations=2000, Archive=91
nodes in the seed set
influence
0
50
100
150
200
250
300
350
400
0
500
1000
1500
2000
HIGHDEG heuristic
SDISC heuristic
MOEA population
MOEA archive

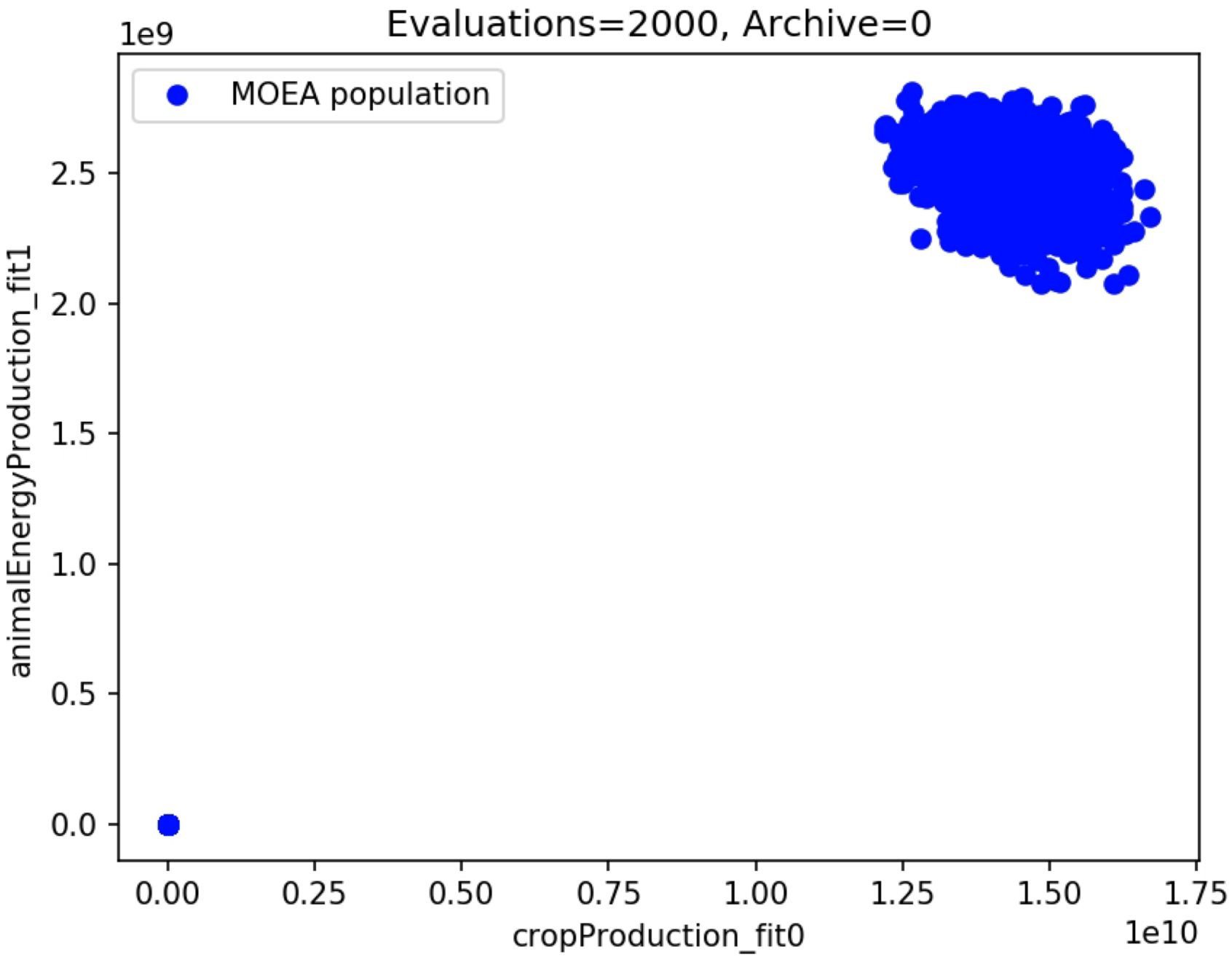
Example: Ecosystem Services

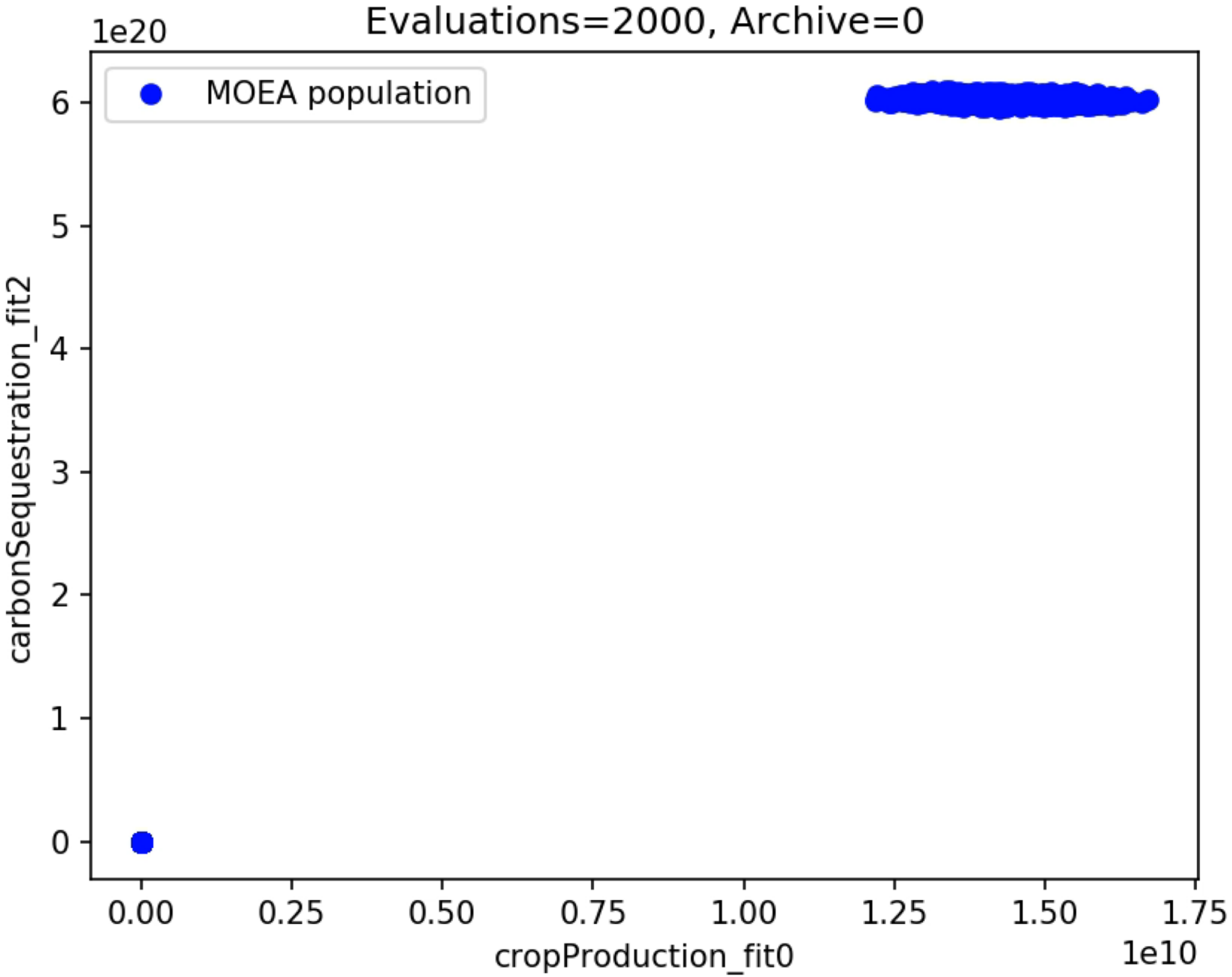
- Optimize land use in agricultural regions
  - Percentage of land assigned to each use
  - Animal feed, crops, forests (carbon sequestration)

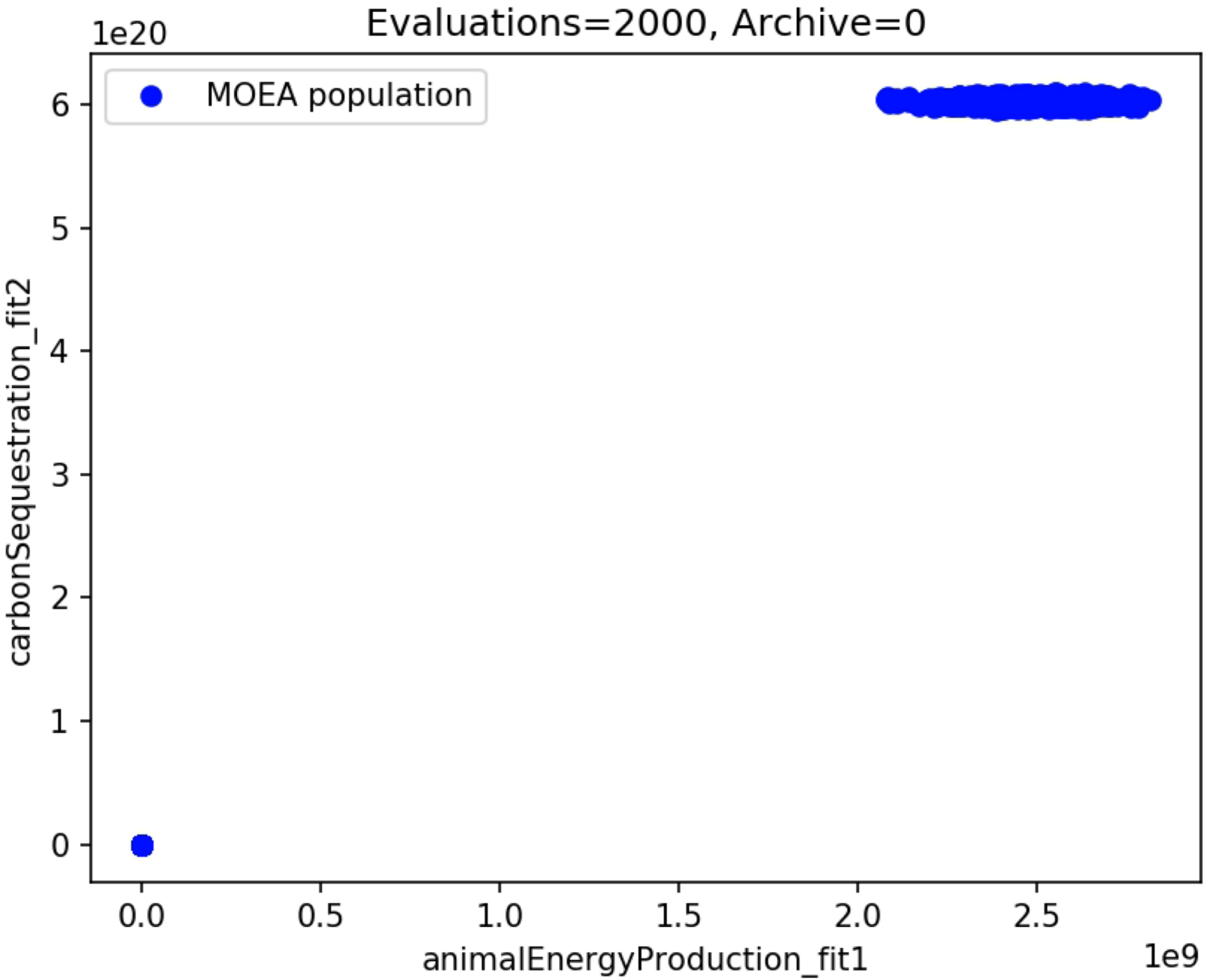
- Multi-objective problem
  - Maximize animal energy production
  - Maximize crop production
  - Maximize carbon sequestration

Example: Ecosystem Services

- Genome (candidate solution)
  - Percentage of land assigned to each task
  - For each region! (~1500 variables for “massive central”)
- Fitness function
  - Model for animal energy production
  - Model for crop production
  - Model for carbon sequestration

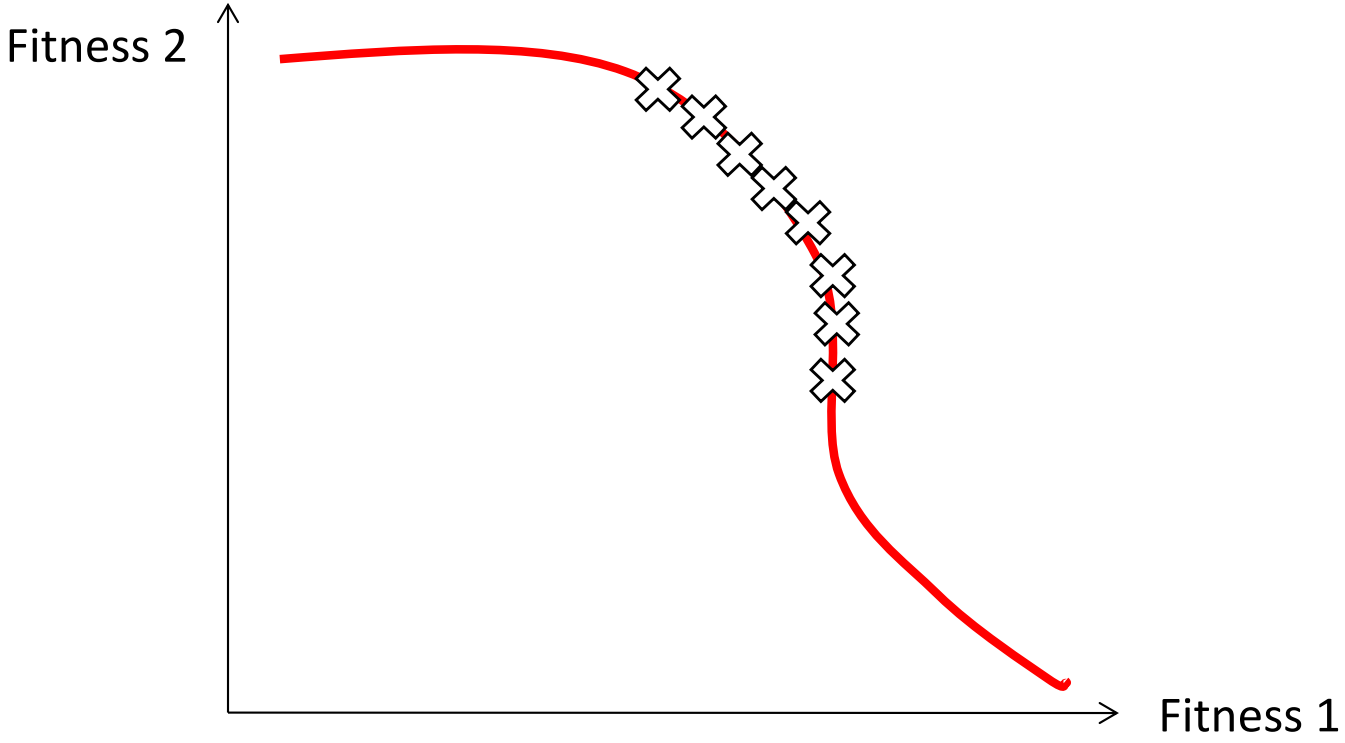

Evaluations=2000, Archive=0
1e9
MOEA population
2.5
2.0
1.5
1.0
0.5
0.0
animalEnergyProduction_fit1
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
cropProduction_fit0
1e10


Evaluations=2000, Archive=0
1e20
MOEA population
6
5
4
3
2
1
0
carbonSequestration_fit2
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
1e10
cropProduction_fit0


Evaluations=2000, Archive=0
1e20
MOEA population
6
5
4
3
2
1
0
carbonSequestration_fit2
0.0
0.5
1.0
1.5
2.0
2.5
animalEnergyProduction_fit1
1e9

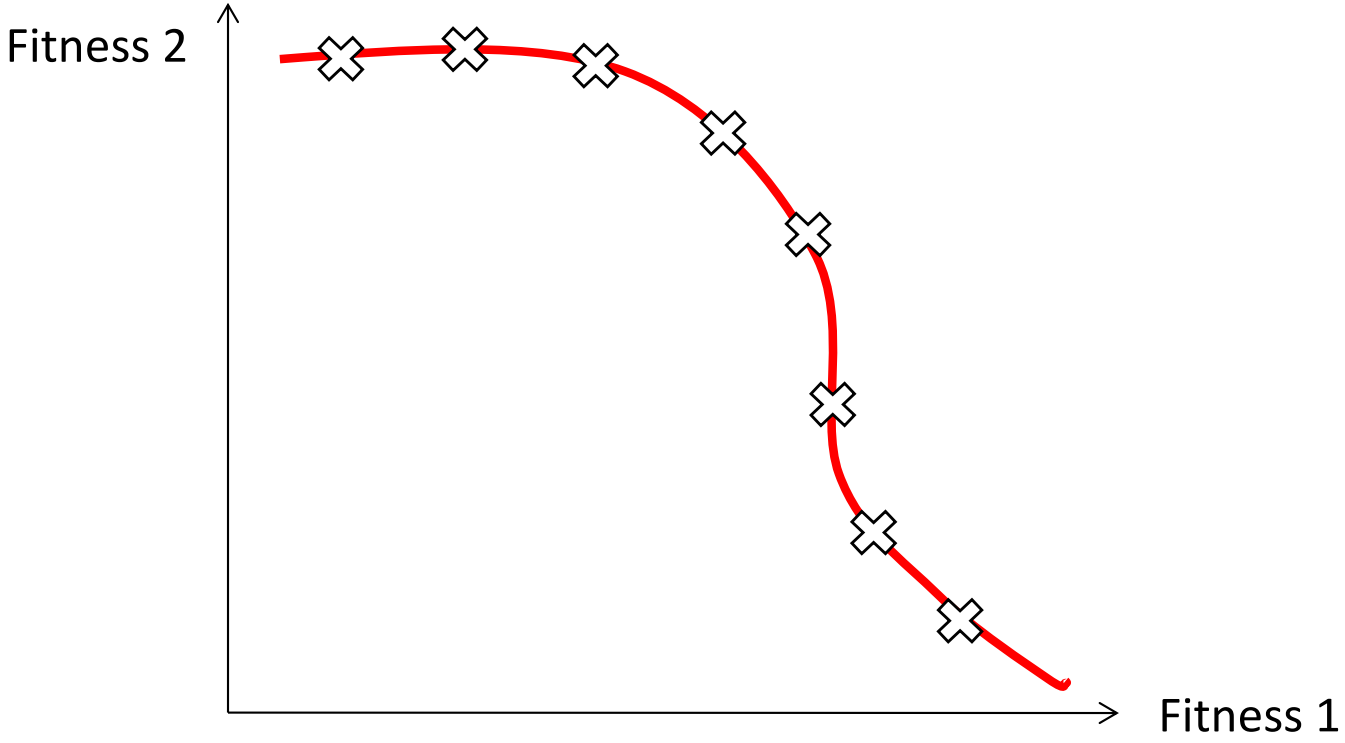
NSGA-II
(Non-Sorting Genetic Algorithm 2)

- *Crowding* can be an issue
  - Too many points too close together on the PF
  - Not really interesting…



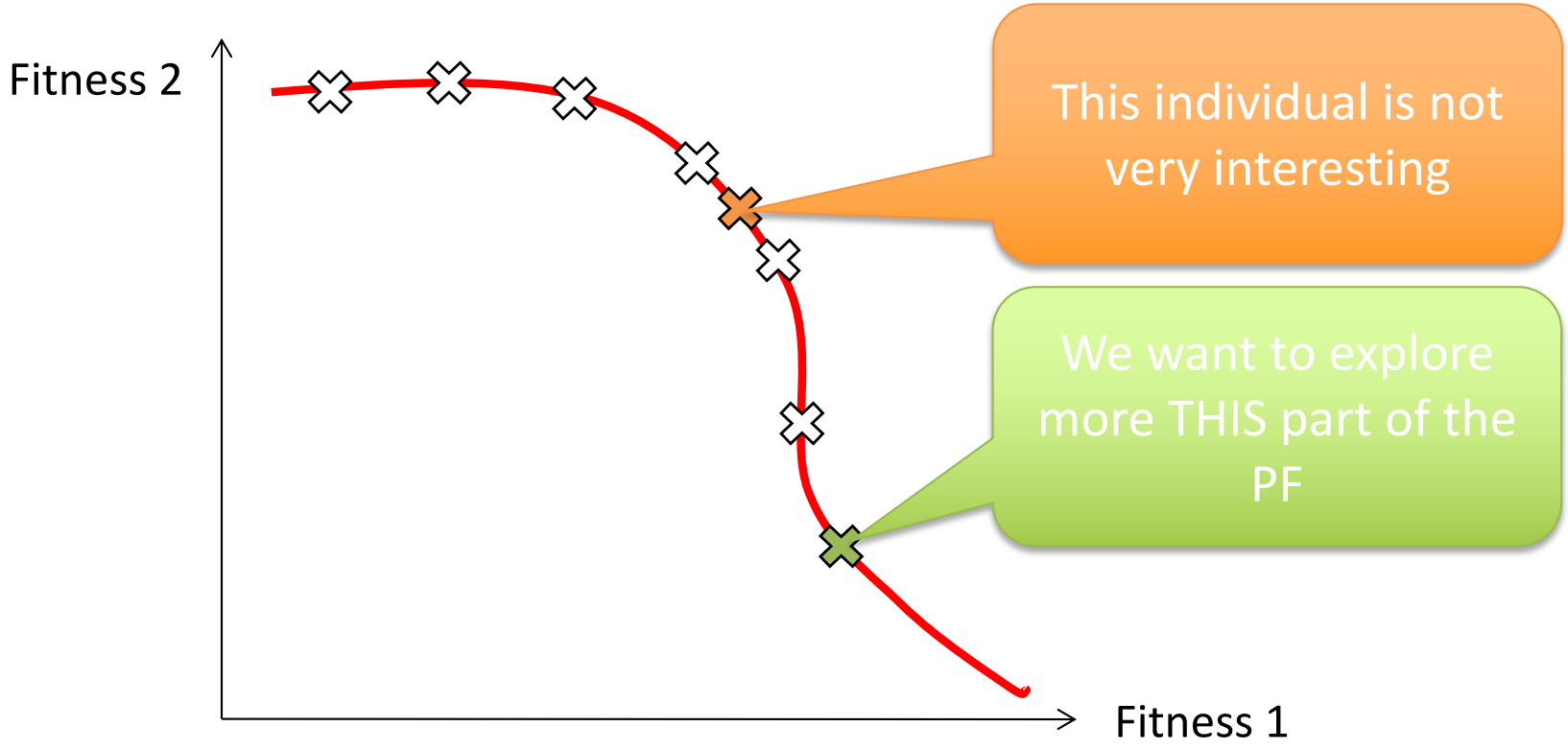
NSGA-II

- *Crowding* can be an issue
  - Ideally, you would like to explore the PF
  - Distribute points “evenly” on the PF



NSGA-II

- Crowding distance
  - Value associated to individuals
  - Used to select for reproduction/survival



NSGA-II

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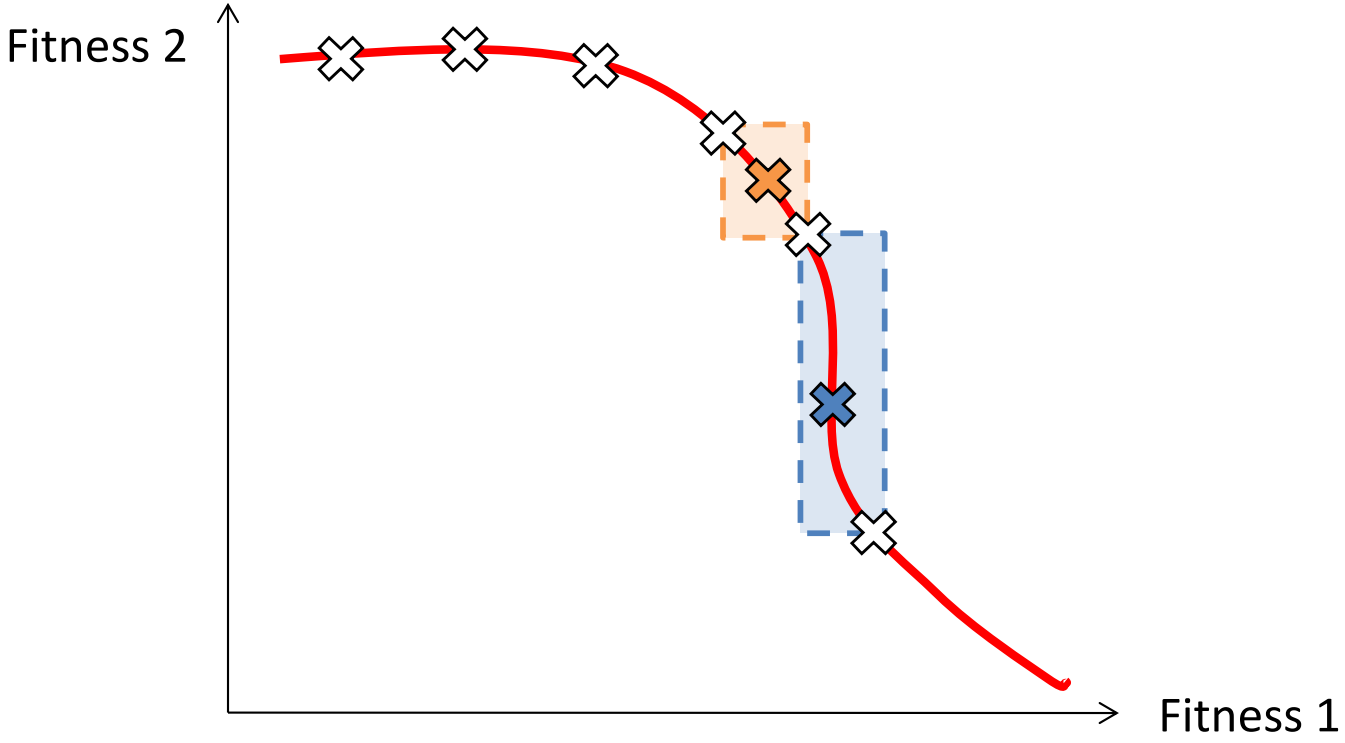

NSGA-II

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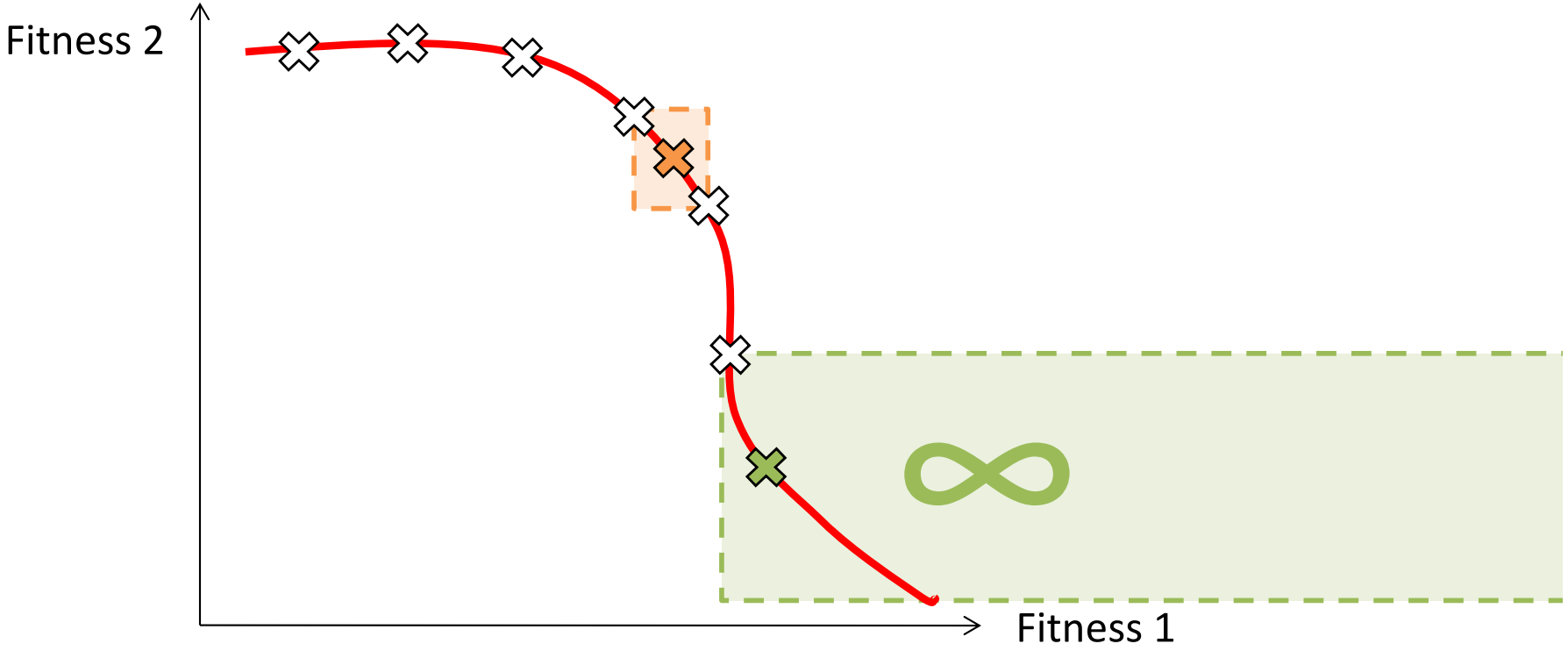

NSGA-II

- NSGA-II (Non-Sorting Genetic Algorithm 2)
  - Crowding distance is a volume for 3 objectives, hypervolume for 4+ objectives
  - For 2 or 3 objectives, it works *really well*

- Limitations
  - The more objectives, the less effective
  - In 10+ dimensions, all points have similar crowding distances

MANY-Objective Optimization…?

- Recent research topic (2016+)
  - What do we do for 10+ objectives?
  - There's **no good answer** (yet)

- Clever ideas
  - Perform dimensionality reduction (NSGA-II+PCA)
  - Use individuals as references (NSGA-III)

Questions?