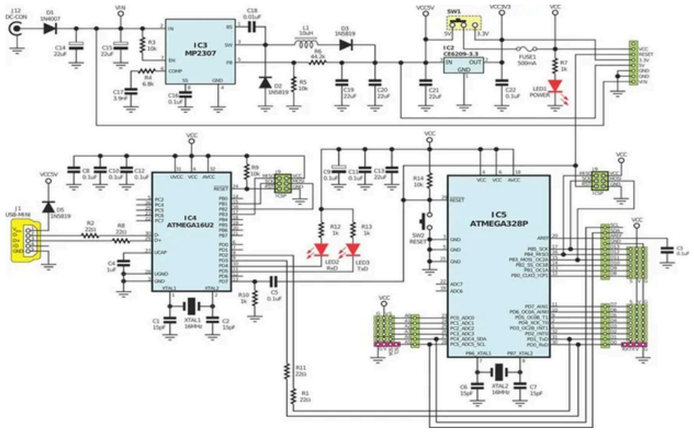
Tonet Lorenzo - Data Science and Artificial Intelligence

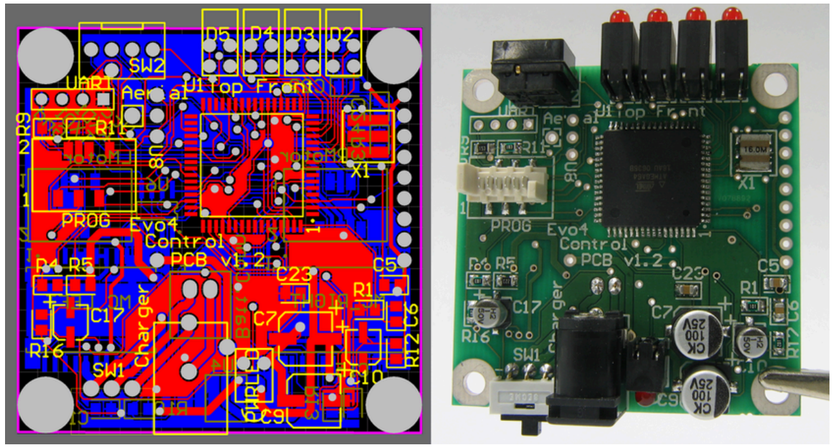
PCB – layout optimization

OPTIMIZATION FOR AI - FINAL PROJECT

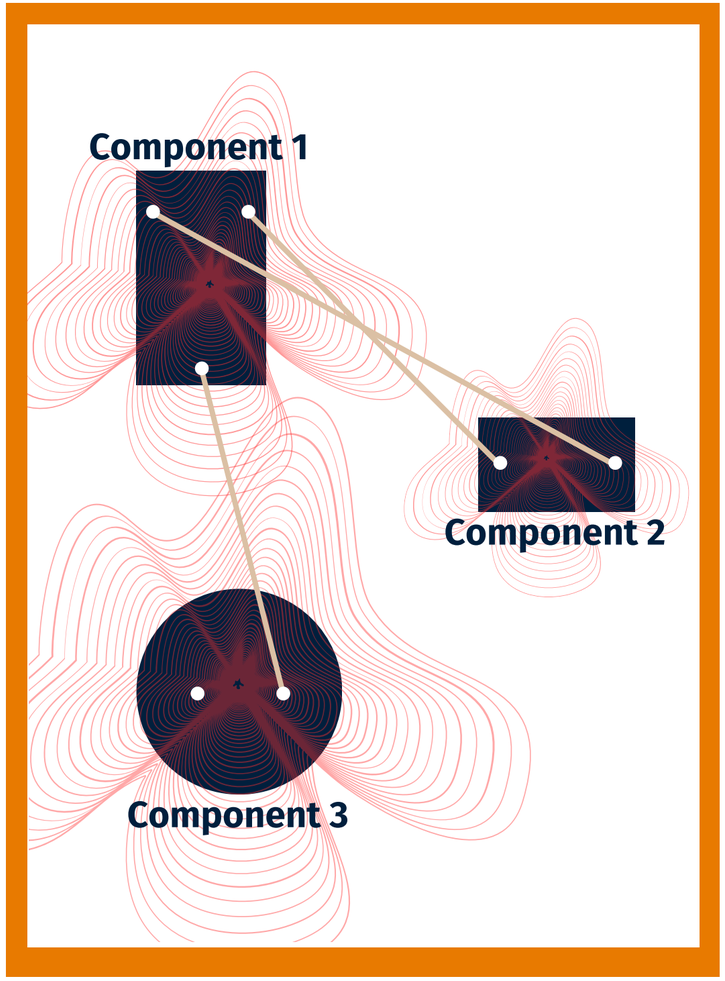
General problem

PCB layout optimization is the problem of **placing** and **routing** electronic components on a circuit board so as to satisfy electrical, thermal, and manufacturing constraints while minimizing objectives such as signal interference, area, or cost.





Problem definition



The PCB will be composed by a list of **Components** and a list of **links** (pins that need to be connected in the circuit)

Every single component is characterized by:

- center position
- rotation angle
- shape (and size)
- set of pins with their relative position
- thermal field

$$f(x) = T_C \times exp\left(-\frac{d(x, x_c)}{d_L}\right)$$

Distance from the center

Temperature at the center

Dissipation length

Genotype to Phenotype

Individual:
PCB

Component 1

center position: (x,y)
angle: 30

Component 2

center position: (x,y)
angle: 25

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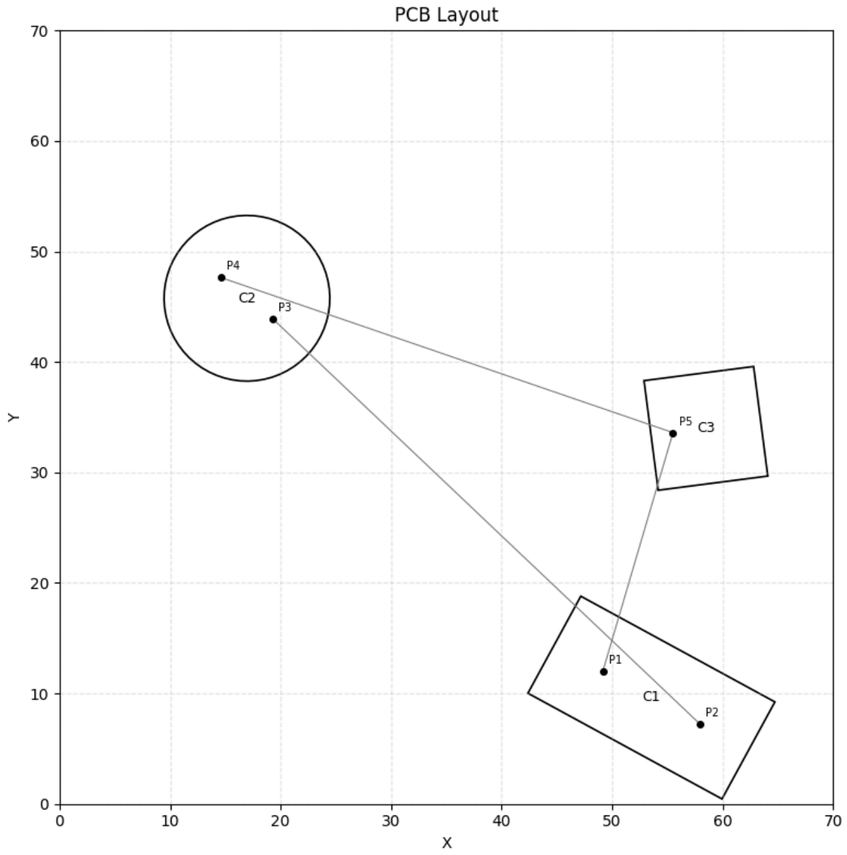
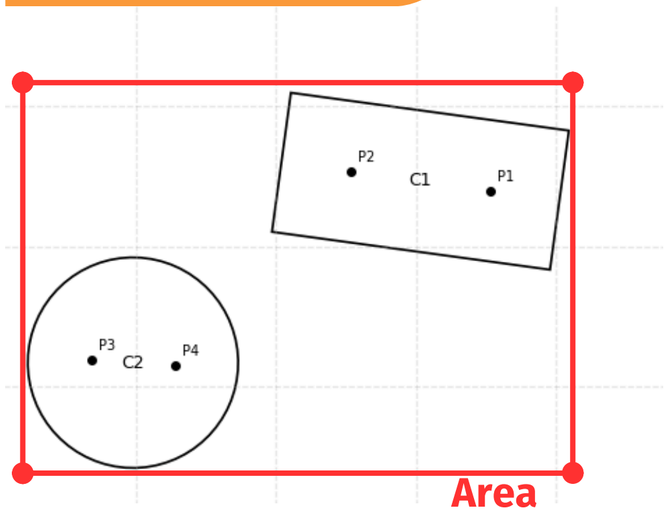
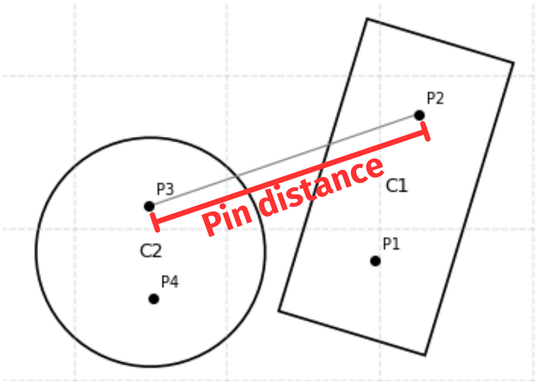


Objective functions

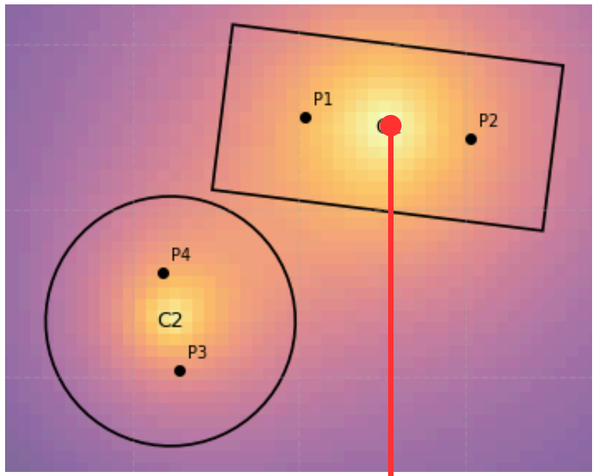
- Occupied Area



- Pin Distance



- Max Temperature

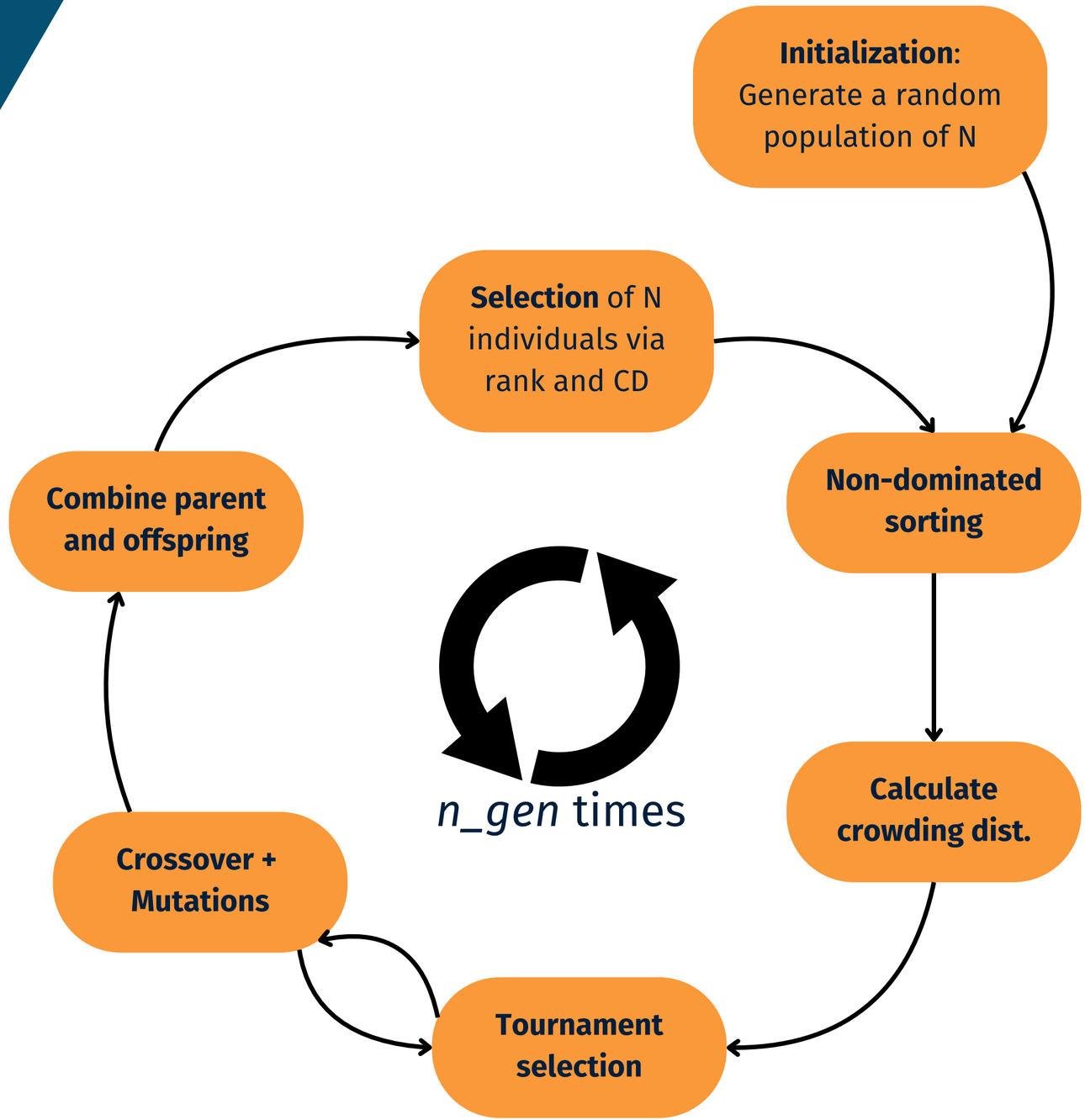


Maximum temperature in the board

Occupied area and **pin distance** define concordant objectives, since both push the layout toward more compact placements, while maximum temperature acts as a conflicting objective that promotes component spreading.

Framework: NSGA-II

- Multi-objective optimization through **non-dominated sorting**
- **Elitism**
- Diversity by **Crowding distance**
- **Tournament selection**



A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II

Kalyanmoy Deb, *Associate Member, IEEE*, Amrit Pratap, Sameer Agarwal, and T. Meyarivan

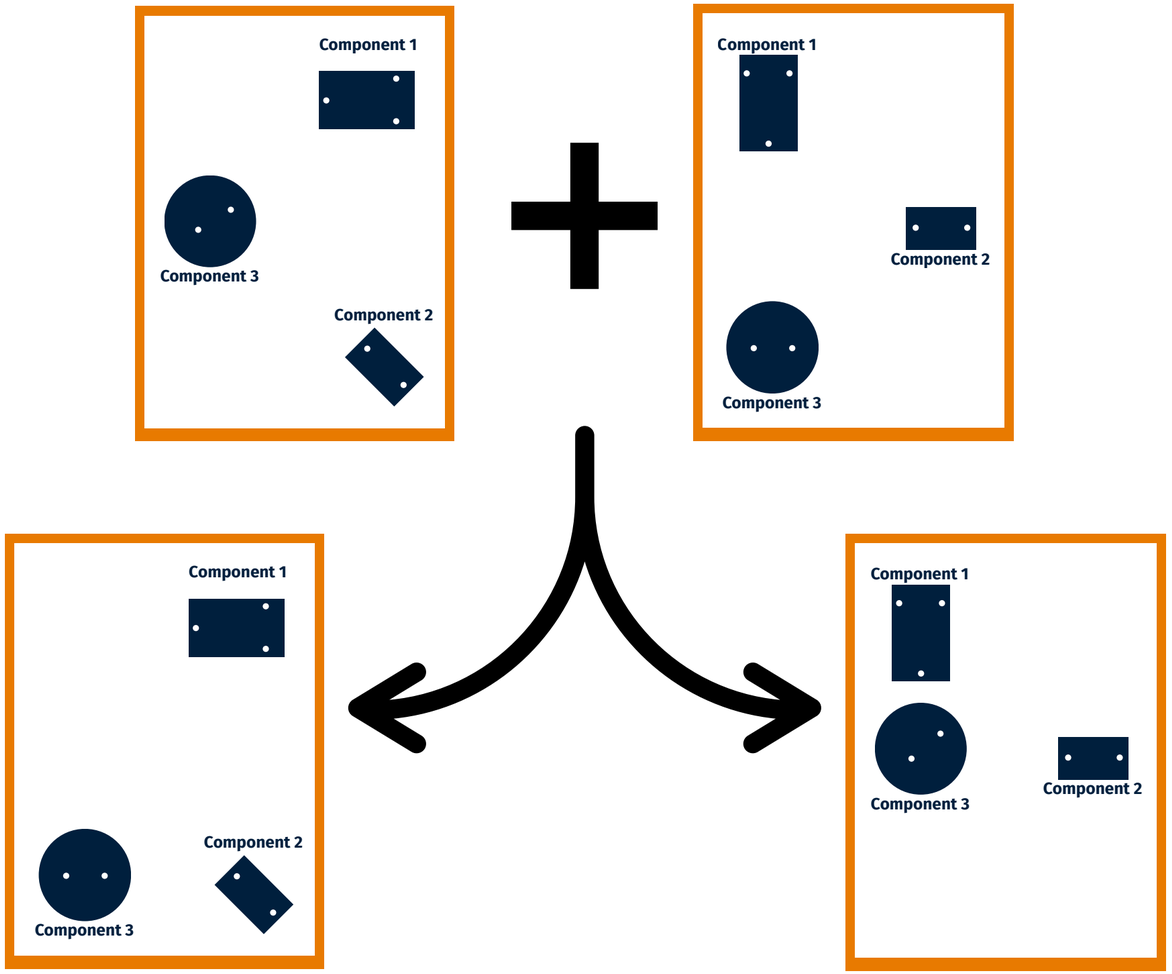
***Abstract*—Multiobjective evolutionary algorithms (EAs) that use nondominated sorting and sharing have been criticized mainly for their: 1) $O(MN^3)$ computational complexity (where M is the number of objectives and N is the population size); 2) nonelitism approach; and 3) the need for specifying a sharing parameter. In this paper, we suggest a nondominated sorting-based multiobjective EA (MOEA), called nondominated**

[20], [26]. The primary reason for this is their ability to find multiple Pareto-optimal solutions in one single simulation run. Since evolutionary algorithms (EAs) work with a population of solutions, a simple EA can be extended to maintain a diverse set of solutions. With an emphasis for moving toward the true Pareto-optimal region, an EA can be used to find multiple

Crossover operator

The crossover operation is characterized by 3 operations:

- select n random components from parents
- swap their position and angle
- resolve emerged conlficts



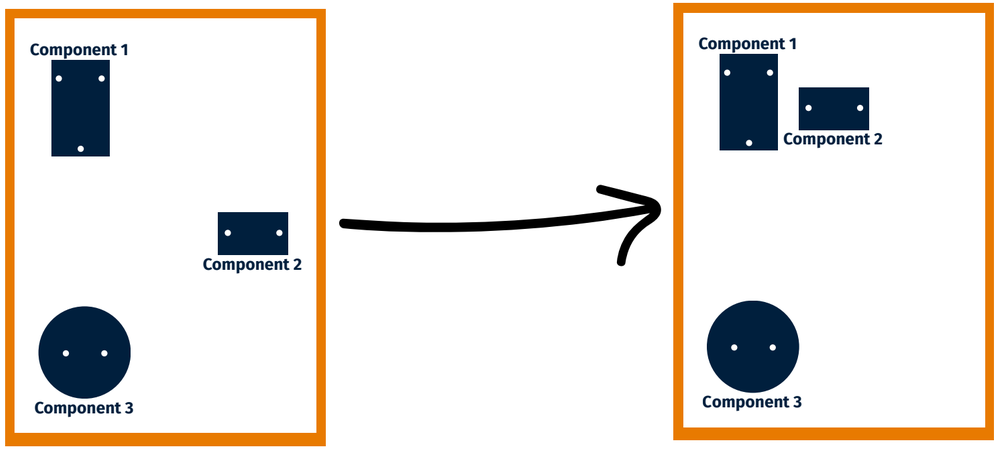
`+resolve_conflicts(max_iterations)`

Mutation Operators

Position Mutation

The first mutation operator is characterized by 3 operations:

- select a random component
- sample a new random position
- move the coponent in the new position
- resolve emerged conlficts

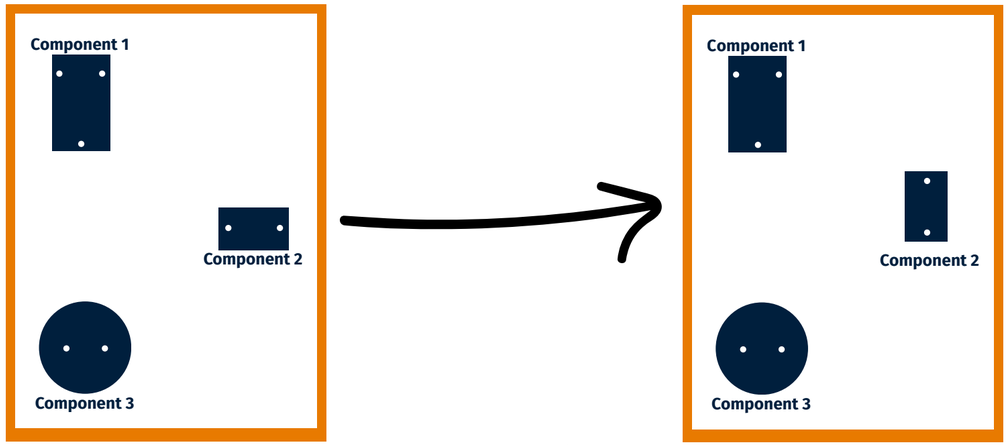


`+resolve_conflicts(max_iterations)`

Rotation Mutation

The second mutation operator is also characterized by 3 operations:

- select a random component
- sample a new angle
- rotate the component
- resolve emerged conlficts

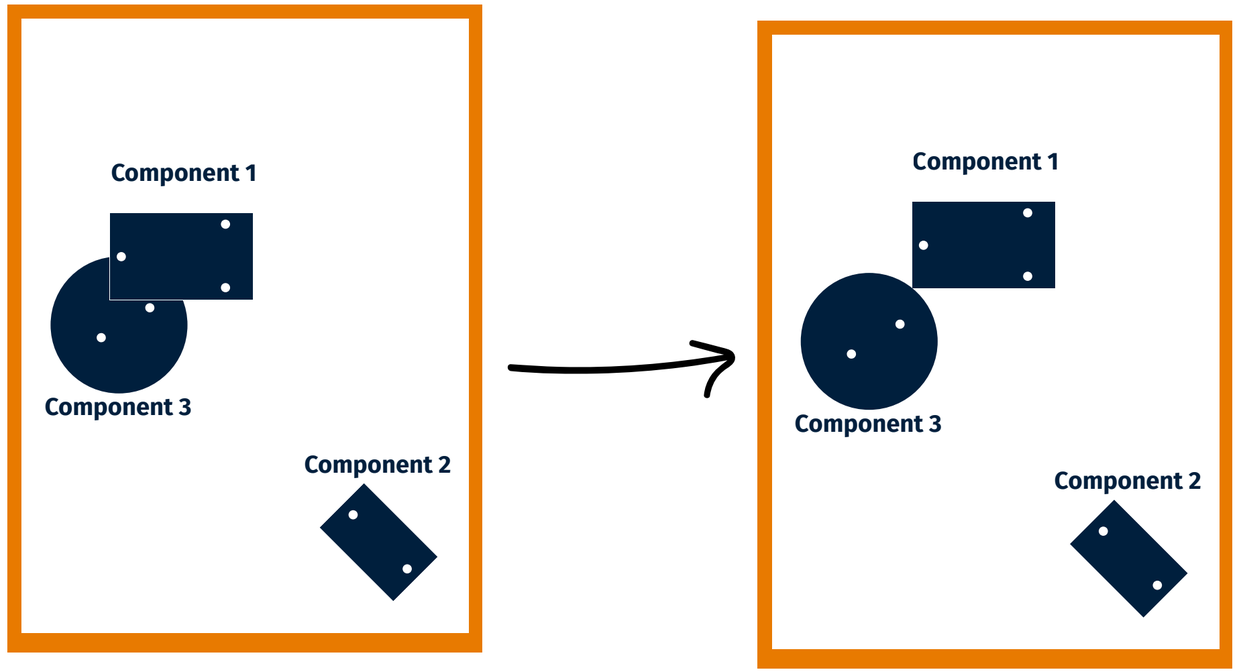


`+resolve_conflicts(max_iterations)`

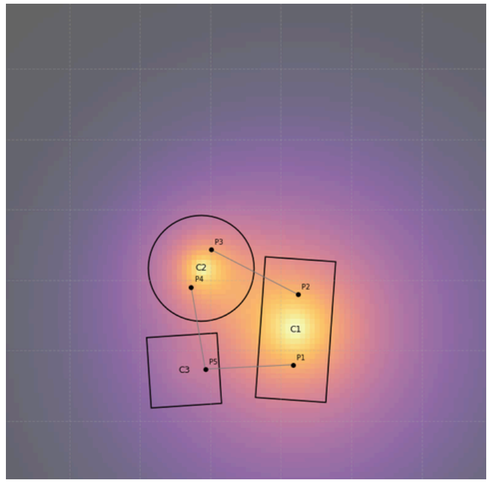
Resolve-conflicts operator

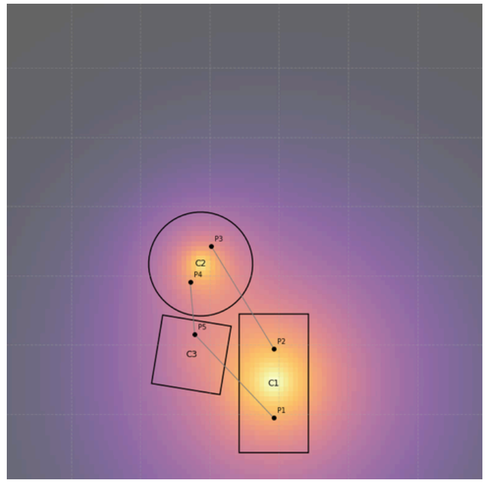
This operator is necessary to **produce valid individuals**. The involved process repeats for a selected number **n** of iterations:

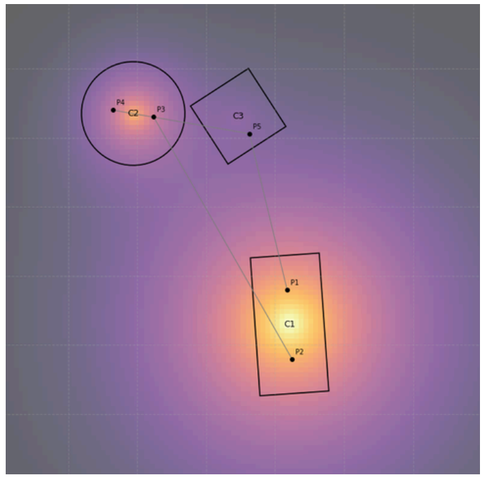
- find all overlaps
- for every overlap:
  - calculate the overlap area
  - move_distance = sqrt(overlap_area) + 1
  - move one of the two components in the opposite direction from the other of move_distance
  - (if can’t move the component because of boundary conditions, move the other)



Results



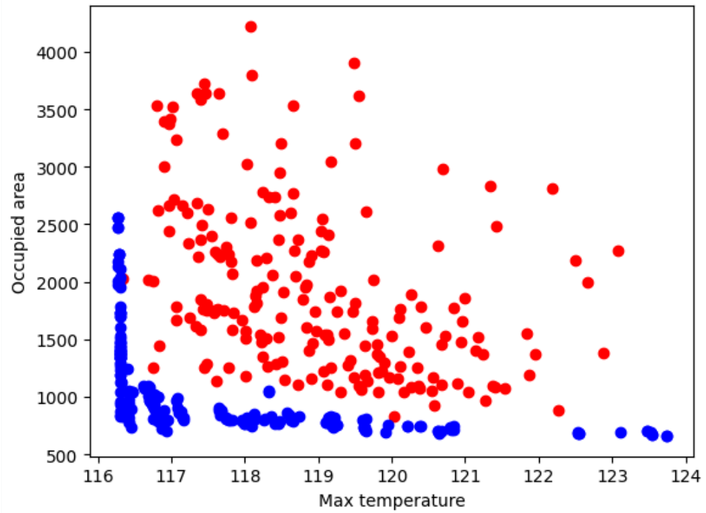


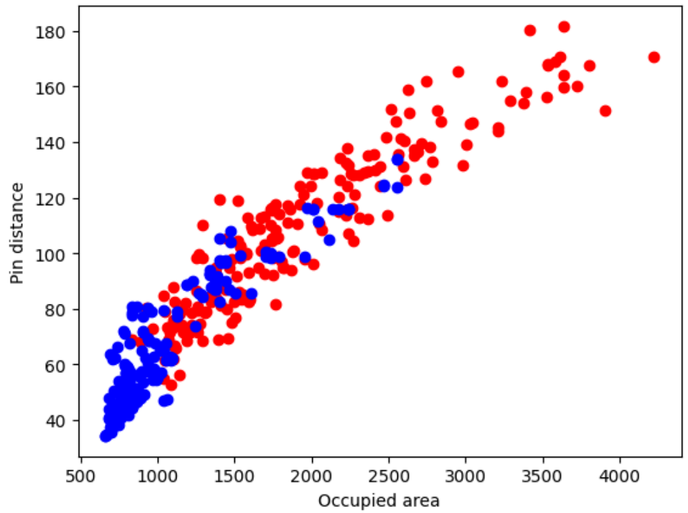


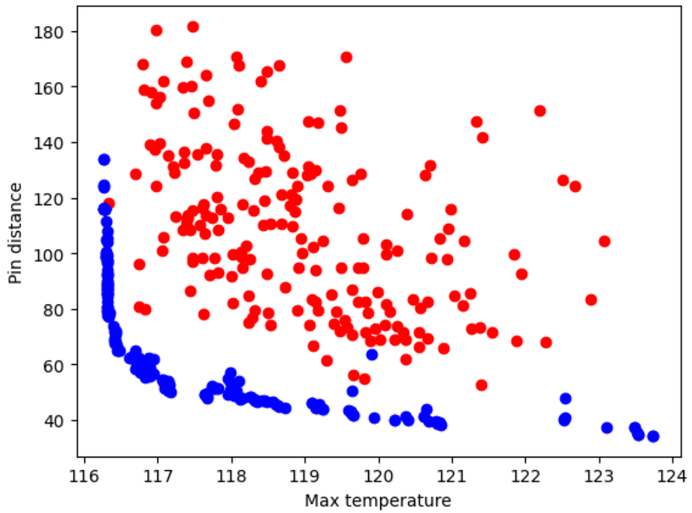
Genetic Algorithm parameters
number_of_generations = 100
population_size = 200

Mutation
rotation_mutation_rate = 0.4
position_mutation_rate = 0.2

Crossover
crossover_rate = 1
components_cross = 1

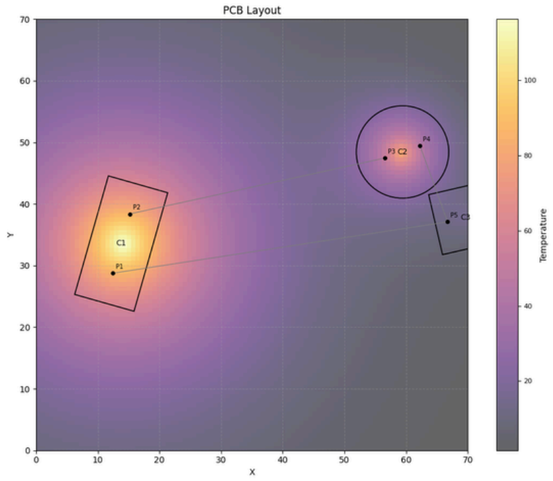






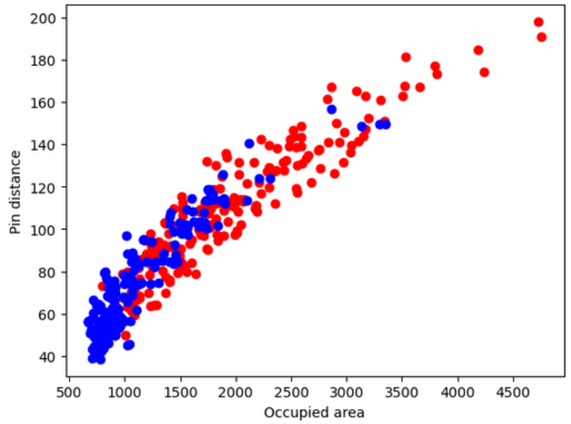
Observations

- By empirical test, it is possible to see how the **crossover helps in maintaining solution diversity**.
- From real-world experience, we know that some solutions on the Pareto front are **impractical, even though they are technically optimal**.
- In real-life problems like this, **objectives can be correlated** between them and share the same type of bounds.

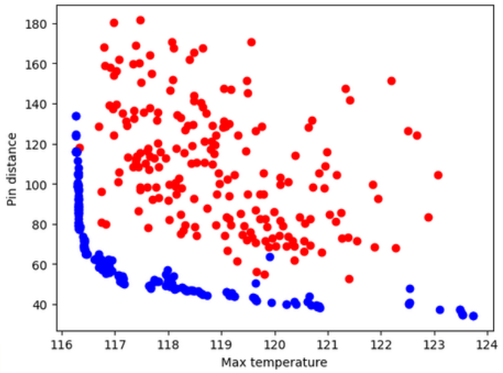


“Good” for temperature but impractical

High correlation between pin distance and occupied area

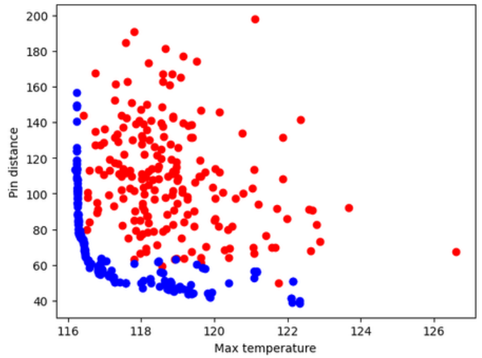


crossover_rate = 1



VS

crossover_rate = 0.9



THE END

Bibliography:

- *“A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II” - Kalyanmoy Deb, Amrit Pratap, Sameer Agarwal, and T. Meyarivan*

Implementation:

- https://github.com/LorenzoTonet/PCB_Layout_Optimization/tree/main