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Evolutionary Many-objective Optimization by MO-NSGA-II with Enhanced Mating Selection

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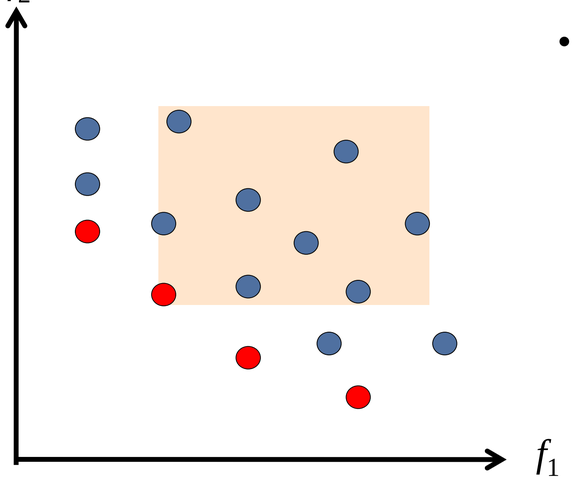
Multiobjective Optimization & Many-objective Optimization

- **Problem**: Minimize $F(x) = \{f_1(x), f_2(x), \ldots f_M(x)\}$
- **Dominance**: $F(x) < F(y)$ iff
  (1) $f_i(x) \le f_i(y)\ \forall\ i,\ 1 \le i \le M$
  (2) $f_i(x) < f_i(y)\ \exists\ i,\ 1 \le i \le M$
- **Pareto optimal**:
  x is Pareto optimal iff $F(x)$ is not dominated by any solution.
- **Goal**:
  Find or approximate the set of Pareto optimal solutions.

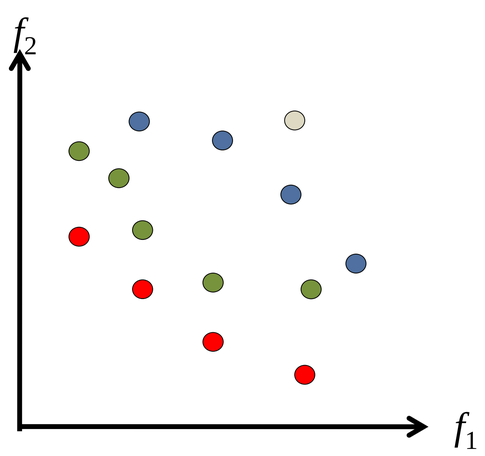


- **Many-objective optimization**: $M \ge 4$
- The exponential increase of non-dominated solutions causes **challenges**:
  - performance deterioration of dominance-based selection
  - representation of the Pareto front
  - diversity preservation
  - visualization

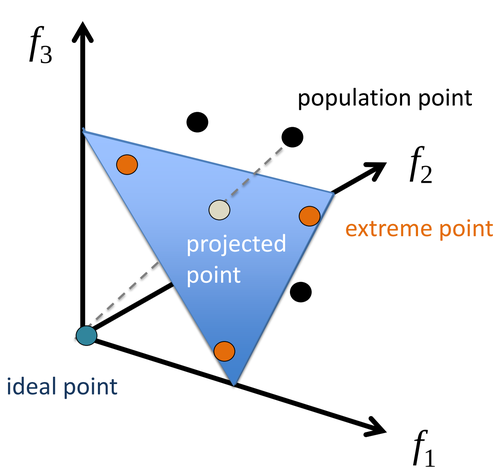
Many Objective Non-dominated Sorting Genetic Algorithm II (MO-NSGA-II)

Deb and Jain (WCCI 2012)

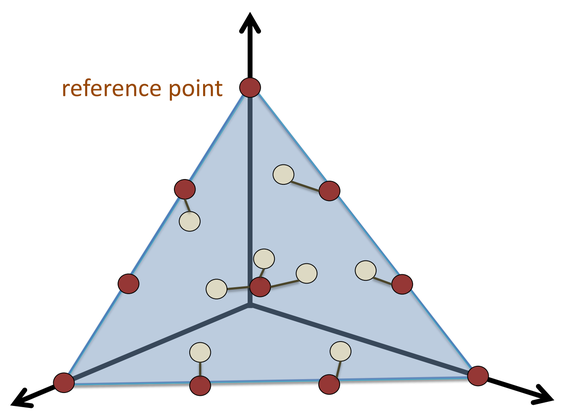
- **Non-dominated sorting**



- **Hyperplane**



- **Reference point & Clustering**



- **Mating & Environmental Selection**

better non-domination level
↓
larger deficiency count
↓
smaller ASF value

$$ASF(x, w) = \max_{i=1,\ldots,M}\{\ (f_i(x) - f_i^*)/w_i\ \}$$

MO-NSGA-II with Enhanced Mating Selection (EMS-MO-NSGA-II)

- **Hierarchical selection:**
  Choose a reference point, then a population member

  (1) RP-U: Choose a reference point randomly

  (2) RP-P: Choose a reference point by roulette wheel w.r.t. the deficiency count.

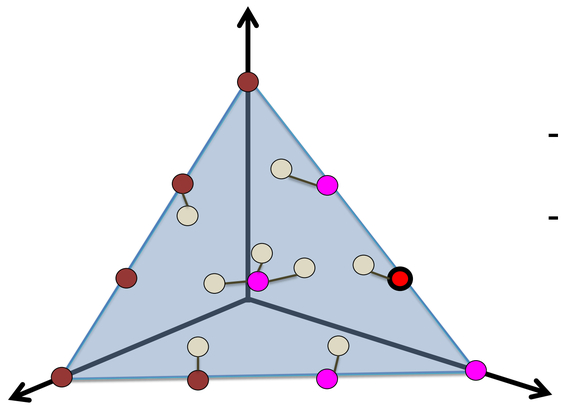
  (3) RP-W: Choose only reference points with large average ASF value.

  RP-W-a: activated at the beginning

  RP-W-d: activated when each reference point has at least one member

  RP-W-g: activated after g% of generations

- **Neighborhood selection:**
  An individual mates only with those associated with neighboring reference points.



- Select the first parent by any selection method.
- Select the second parent randomly from the clusters of neighboring reference points.

Experimental Results

- **Benchmark instances:**
  - DTLZ1-4 (M = 3, 5, 8, and 10)
- **Performance measures:**
  - inverted generational distance (IGD)
  - additive epsilon indicator
- **Experimental setting:**
  - simulated binary crossover (SBX)
  - polynomial mutation
  - 20 runs
  - Mann Whitney rank sum test

- **Exp. 1: Hierarchical selection:**
  - RP-U and RP-P do not have significant effect.
  - RP-W-a and RP-W-d are not good, but RP-W-g can significantly improve the performance. (RP-W-90 outperforms the original method in 11 instances and is outperformed in none.)
- **Exp 2: Neighborhood selection:**
  - It is useful to improve the performance, and the performance is not sensitive to the neighborhood size.
- **Exp 3: MO-NSGA-II vs. EMS-MO-NSGA-II**
  - EMS-MO-NSGA-II is better in 12 instances and worse in 1 instance.