2024 resume and 2025 plan

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Research

Exact algorithms to find the Pareto front in combinatorial optimization

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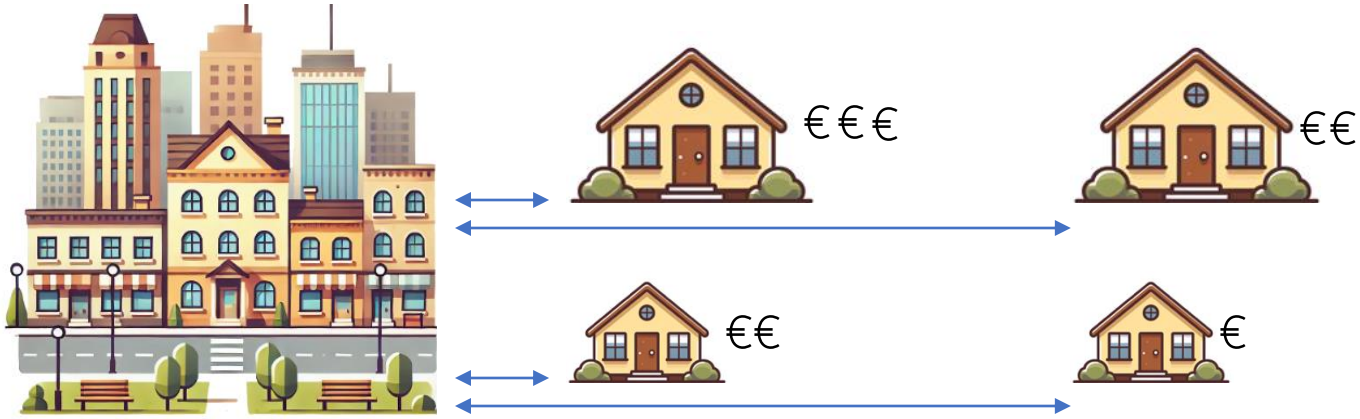
Single objective optimization

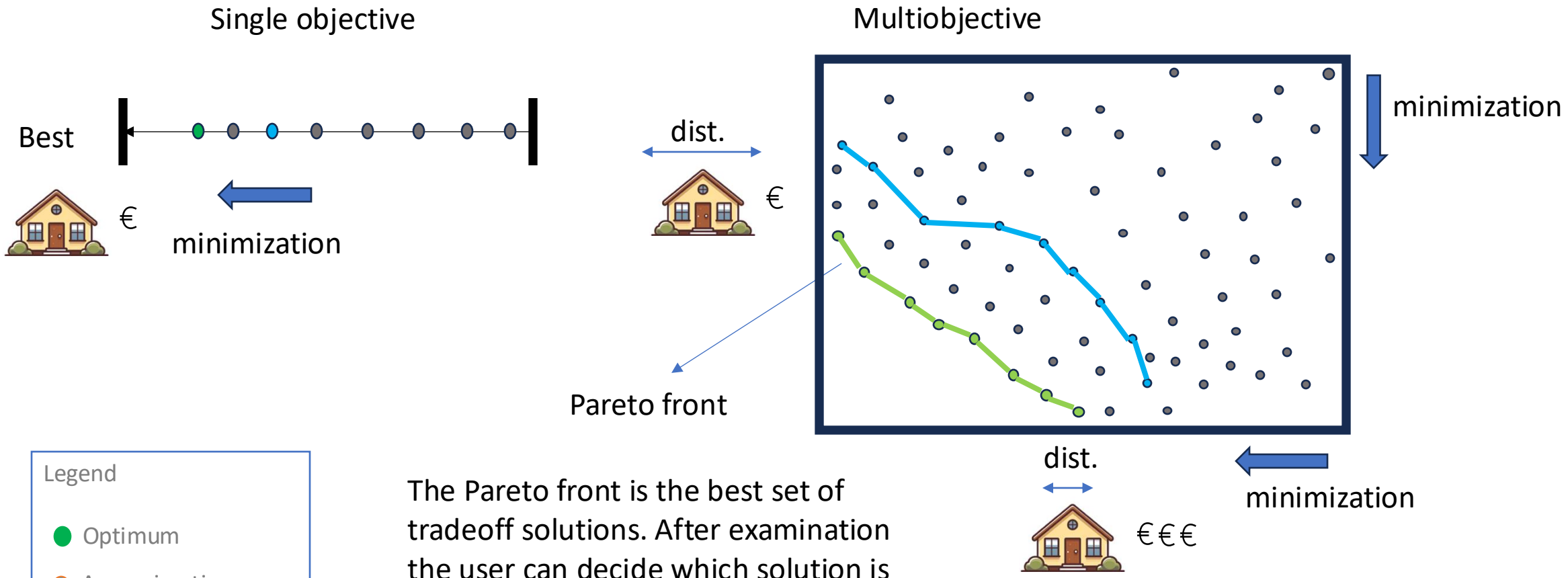
- Only one objective to optimize.
- Traveling Salesman Problem (TSP).
  - Tour with minimum total distance.
- Defined by $\mathbf{min}\ (\mathbf{f}(\mathbf{x}))$, s.t.
  - $x \in S$,
  - S feasible region

Multiobjective optimization

- More than one objective to optimize.
- Defined by (x)) $\boldsymbol{min}\ (\boldsymbol{f_1(x), f_2(x), \ldots, f_p})$, s.t.
  - $x \in S$,
  - S feasible region
- Objectives in opposition. Ex: Buying a house
  - Maximize size, minimize price and distance to downtown.



Multiobjective optimization solution



The Pareto front is the best set of tradeoff solutions. After examination the user can decide which solution is the best.

Find the Pareto front (or subset)

Why find the Pareto front and not an approximation:

- Used with exact methods (CP, SAT, MILP).
- For simple problems or small instances of hard problems, it is possible to find the Pareto front.
- To obtain a subset of the Pareto front:
    - Pareto front is too big, a small representation is ok for the user, e.g. 20 points.
    - Obtain a small subset to serve as input to heuristics to find a larger approximation to the Pareto front. For example, it can be used in combination with Pareto Local Search.

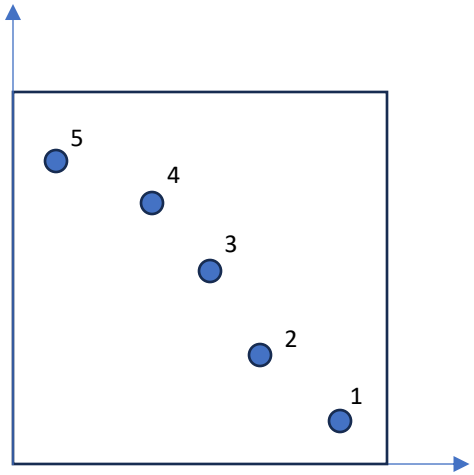
State of the art

- ϵ-constraint: Saugmecon[1]
- Image space methods: Disjunctive programming[2]
- **Constraint satisfaction methods**:
  - Gavanelli[3] and Pierre Schaus[4]. Implemented in CP solver Choco
    - **Is the most used in the CP community**
  - **Guided Improvement Algorithm (GIA)[5]**

1. Weihua Zhang and Marc Reimann. A simple augmented ε-constraint method for multi-objective mathematical integer programming problems. European Journal of Operational Research,234(1):15–24, apr 2014. doi:10.1016/j.ejor.2013.09.001
2. Tolga Bektaş (2018) Disjunctive Programming for Multiobjective Discrete Optimisation. INFORMS Journal on Computing 30(4):625-633. https://doi.org/10.1287/ijoc.2017.0804
3. Gavanelli, M.: An algorithm for multi-criteria optimization in CSPs. Ecai. 2–6 (2002).
4. Schaus, P., Hartert, R.: Multi-objective large neighborhood search. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). pp. 611–627. Springer, Berlin, Heidelberg (2013). https://doi.org/10.1007/978-3-642-40627-0_46.
5. Jackson, D., Estler, H.-C., Rayside, D.: The Guided Improvement Algorithm for Exact, General-Purpose, Many-Objective Combinatorial Optimization. (2009).

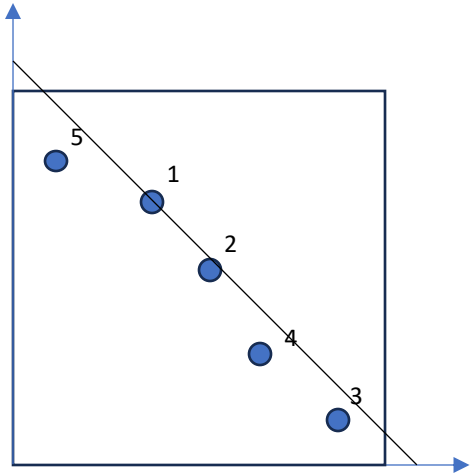
State of the art (assume maximization)

Saugmecon



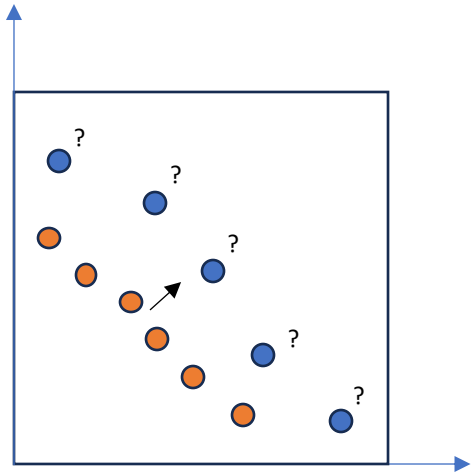
Find the points from one corner to another

Disjunctive (max f1+f2)



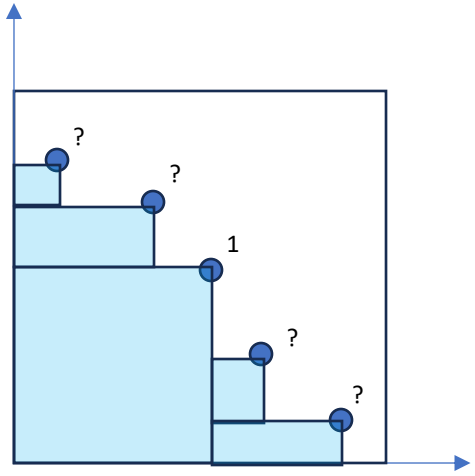
Find the points with weighted sum. Coverage is affected, as points in the non-convex area are not found at the right time

Gavanelli



Before finishing it is impossible to know if a point belongs to the front or not

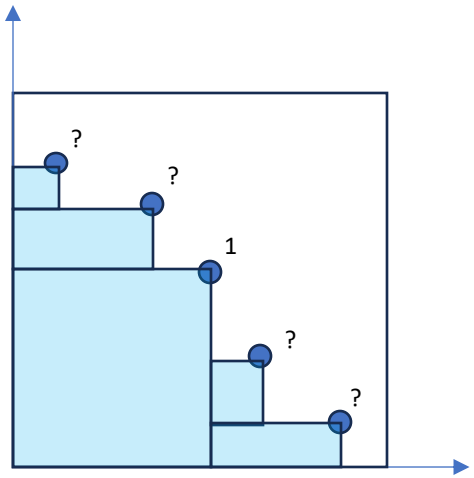
GIA



It uses only LB to find next point. No control on how to get the next point

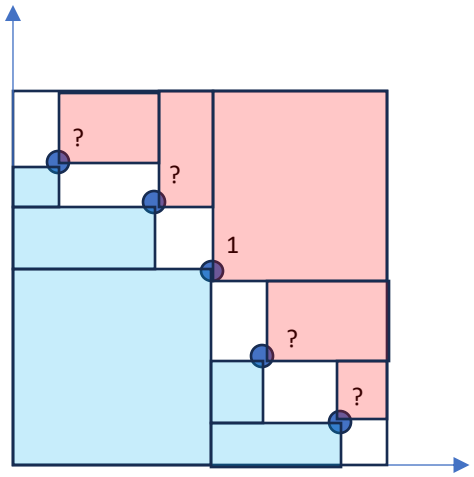
Proposed algorithm

GIA



It uses only LB to find next point. No control on how to get the next point

GIA bounded



It uses the property of the Pareto points to set the LB and UB to find next point

- It is useful especially in constraint programming to reduce the domain of the objective variables.
- In performed experiments with this approach less backtracking and less explored nodes.

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2024

What have been accomplished

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Research related activities

- Implementation in MILP solver Gurobi of a version of GIA using lazy constraints.
    - Perform experiments in Gurobi comparing Saugmecon, Gavanelli and GIA. Benchmark Satellite Image Selection Problem considering only cost and clouds(SIMScc).
- CP Winter School. Learn about Choco and propagator design for a more efficient implementation of GIA.
- Implementation in CP solver Choco of Saugmecon, GIA, Disjunctive approach, GIA_bounded, and GIA_bounded with region selection to improve coverage for bi-objectives problems.
    - Implement in a more efficient way using a global constraint similar to the one used in Gavanelli.
    - Perform experiments comparing Saugmecon, Disjunctive approach, Gavanelli, GIA and GIA_bounded. Benchmarks: SIMScc, Bi-objective Knapsack, Autmotive (too hard), Flowshop Taillard (too hard).
- Literature review of algorithms based on GIA or algorithms that are compared to GIA.

Research related activities

- Lecture about multi-objective optimization in course Problem Solving.
- Collaboration with the Polish team in paper based on SIMS.
    - Coding another algorithm to find a spread subset of the Pareto front in Gurobi.
    - Write description of the algorithm in the paper.

Standardisation activities

- World Standards Day 10/2023
- Contribution to a second white paper “Extending geographic information imagery standards for mosaic generation”
    - Standards for satellite images.
    - Considerations for mosaic creation and multiobjective mosaic creation.
- Partnership day 05/2024.
- Maintenance of “ILNAS-SnT Research Programme 2021-2024” website.

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2025

Main goals

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Goals 2025

- Try to publish the obtained results comparing Gavanelli, Saugmecon, GIA and GIA_bounded.
    - Perform experiments for 3 objectives in SIMS (4 objectives in SIMS could be hard), 3, 4 and 5 objectives in Knapsack, and other problems, maybe TSP or assignment problems.
- Implement possible improvements to the current method.
    - Add a stop condition to avoid searching for a solution too long.
    - Combine with the Disjunctive approach to find a subset of the Pareto front with good coverage.
        - Compare with other strategies that aim to maximize coverage.
    - Publish results in conference paper.

Goals 2025

- Try to unify Gavanelli, GIA and Saugmecon as a single algorithm with configuration parameters.
  - The algorithm can be tuned using hyper parameter optimization.
  - Can be dynamically adapted.
  - Used in a portfolio search with different configurations.
- Write a journal paper with the obtained results.
- Write at least 70% of the manuscript. The thesis defense should be before 01/05/2026.

Immediate goal – paper for fully bounded GIA

Sections

- Abstract
- Introduction
  - Initial draft written. Introduce multi-objective combinatorial optimization -> exact methods -> constraint methods -> flaws in Gavenelli and GIA -> what are the contributions
- Preliminaries
  - Initial draft written. Some important definitions, CP, Pareto dominance, Image space division by dominance
- State of the art
  - Write about the methods based on GIA, it is useful to show that although it was created in 2009, there is still papers proposing improvements (last one in CP 2024) and that any of those propose our idea. I already have a word document with some notes

Immediate goal – paper for fully bounded GIA

Sections

- GIA algorithm
    - Explain the algorithm and put the pseudocde.
    - Explain how we implemented in a constraint solver using Gavanelli global constraint (it was design for SAT solvers)
  - GIA fully bounded. A subsection explaining the improvement
- Experiments. Comparisson between GIA and GIA fully bounded.
    - Hardware
    - Describe the problems and the benchmarks used (SIMS 2,3 objs and KP 2,3,4,5 objs).
    - Table with experiment results and conclusions. Use finishing time and nodes explored as metrics.
- Conclusions. General conclusions