

# Coevolutionary Hybrid Bi-level Optimization (CARBON)

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# Background

## Education

- Bachelor Degree in Computer Science at the University of Lorraine
- Master Degree in Optimization and Algorithmic
- Master thesis: **“Bi-objective satellite power optimisation”**
- PhD started in February 2015
- Defense soon in January

## PhD

Problematic: Bi-level optimization problems

Solution: Hybrid Co-evolutionary algorithms

# Bi-level optimization

## In summary

- Mathematical problems modeling **adversarial** situations
- Related to **Game Theory** and more precisely **Stackelberg Games**
- “*Mathematical programs with optimization problems in the constraints*” (Bracken et al.)

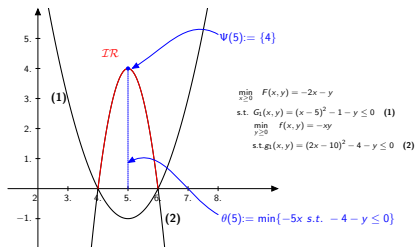
$$\begin{aligned} \min_{x \in \mathbf{X}, y \in \mathbf{Y}} \quad & F(x, y) \\ \text{s.t.} \quad & G(x, y) \leq 0 \\ & \min_{y \in \mathbf{Y}} \quad f(x, y) \\ & \text{s.t.} \quad g(x, y) \leq 0 \end{aligned}$$

Figure: General bi-level optimization problem

# Bi-level properties

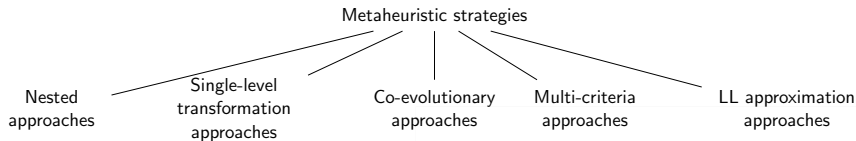
## Properties

- $\mathcal{NP}$ -hard even for two **separated linear levels**
- **Convexity** not sufficient to find optimal solutions in polynomial time
- Exact resolution approaches are unsuitable
- Bi-level **feasibility** implies **lower-level optimality**



Definition	Description
$(x, y)$	Bi-level decision vector
$x$	Upper-level decision vector
$y$	Lower-level decision vector
$F(x, y)$	Upper-level objective function
$f(x, y)$	Lower-level objective function
$G(x, y) \leq 0$	Upper-level set of constraints
$g(x, y) \leq 0$	Lower-level set of constraints
$\theta(x) := \min\{f(x, y) \text{ s.t. } g(x, y) \leq 0\}$	Lower-level optimal value for a given $x$
$\Psi(x) = \{y \in Y : g(x, y) \leq 0, f(x, y) \leq \theta(x)\}$	Lower-level rational decision set
$\mathcal{IR} = \{(x, y), y \in \Psi(x)\}$	solution set mapping Inducible Region

# Bi-level metaheuristics



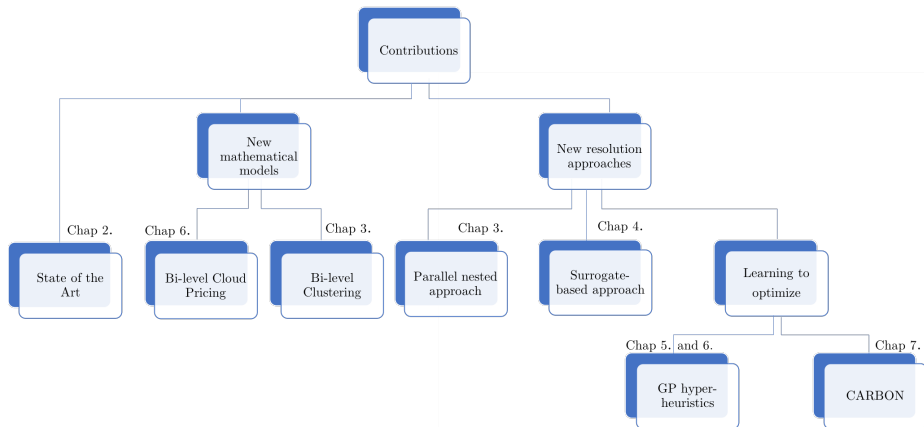
## Characteristics

- Nested opt. is time-consuming
- Reformulation techniques require strong assumptions (e.g., convexity, regularity)
- LL-approx. app. are recent and promising
- **BUT** restricted to small-scale continuous problems
- Co-evolution app. are well-suited for large-scale problems
- **BUT** But bi-level have strong epistatic links between the levels

# Thesis objectives

- **O1: Survey advantages and limitations** of bi-level metaheuristics
- **O2: Propose** novel bi-level model for **real-world applications**
- **O3: Investigate** lower-level optimization **reduction cost**
- **O4: Investigate** decentralized approaches such as **co-evolution**
- **O5: Propose** an **hybrid co-evolutionary** algorithm: **CARBON**

# Thesis content



# Contributions

- E. Kieffer, M. R. Brust, G. Danoy, P. Bouvry, and Anass Nagih. Tackling large-scale and combinatorial bi-level problems with genetic programming hyper-heuristic. *IEEE Transactions on Evolutionary Computation*, (in review), 2018a.
- M. Ostaszewski, E. Kieffer, G. Danoy, R. Schneider, and P. Bouvry. Clustering approaches for visual knowledge exploration in molecular interaction networks. *BMC Bioinformatics*, 19(1), aug 2018.
- E. Kieffer, G. Danoy, P. Bouvry, and A. Nagih. A competitive approach for bi-level co-evolution. In *2018 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)*, pages 609–618, May 2018b.
- E. Kieffer, G. Danoy, P. Bouvry, and A. Nagih. Bayesian optimization approach of general bi-level problems. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, pages 1614–1621. ACM, 2017a. ISBN 978-1-4503-4939-0.
- E. Kieffer, G. Danoy, P. Bouvry, and A. Nagih. A new modeling approach for the biobjective exact optimization of satellite payload configuration. *International Transactions in Operational Research*, 2017b.
- E. Kieffer, G. Danoy, P. Bouvry, and A. Nagih. A new co-evolutionary algorithm based on constraint decomposition. In *2017 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)*, pages 492–500, May 2017c.
- E. Kieffer, G. Danoy, and P. Bouvry. On bi-level approach for scheduling problems. In *New Challenges in Scheduling Theory*, 2016a.
- E. Kieffer, G. Danoy, P. Bouvry, and A. Nagih. Hybrid mobility model with pheromones for uav detection task. In *2016 IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8, Dec 2016b.
- E. Kieffer, M. Guzek, G. Danoy, P. Bouvry, and A. Nagih. A novel co-evolutionary approach for constrained genetic algorithms. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, GECCO '16 Companion, pages 47–48. ACM, 2016c. ISBN 978-1-4503-4323-7.