On Misleading Solutions in Evolutionary Bilevel Optimization

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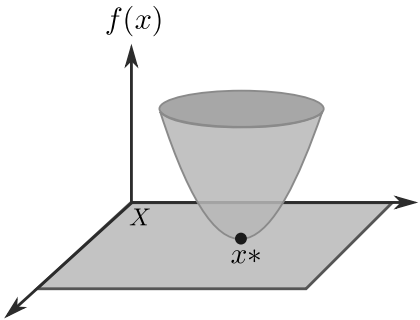
Outline

Bilevel Optimization

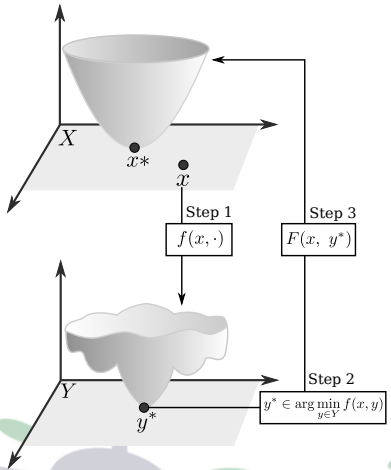


Traditional optimization problem

$$X^* = \arg\min_{\vec{x} \in X} f(\vec{x}) \tag{1}$$
$$= \{\vec{x}^* \in X \ : \ f(\vec{x}^*) \leq f(\vec{x}), \ \forall \vec{x} \in X\},$$

Rao, S. S. (2019). Engineering optimization: theory and practice. John Wiley & Sons.

Nested Scheme



1. Choose an upper level vector of parameters $\vec{x}$.
2. Solve the lower level problem, i.e., find

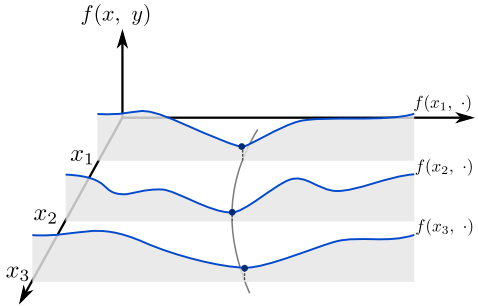
$$\vec{y} \in \Psi(\vec{x}) = \arg\min\{f(\vec{x}, \vec{z}) : \vec{z} \in Y\}.$$

3. Evaluate the feasible solution $F(\vec{x}, \vec{y}^*)$.

Bilevel Optimization problems are strongly NP-hard.

Zhang, G., et al (2015). Multi-level decision making. New York: Springer.

Bilevel Optimization



Minimize

$$F(\vec{x},\ \vec{y})\ \ \vec{x} \in X,\ \vec{y} \in Y \qquad (2)$$

subject to:

$$\vec{y} \in \arg\min\{f(\vec{x},\vec{y})\ :\ g_j(\vec{x},\vec{y}) \leq 0,\ j \in J\}$$

Dempe, Stephan. Foundations of bilevel programming. Springer Science & Business Media, 2002.

How BO problems are solved?

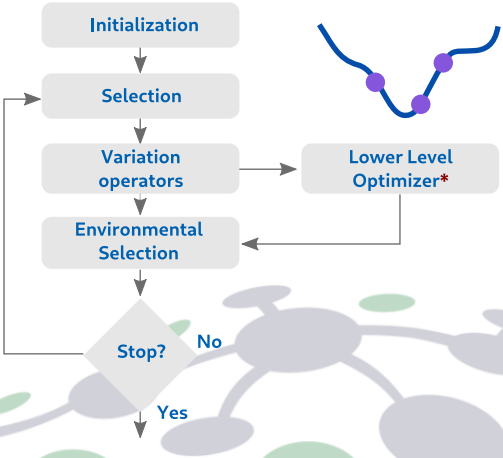
Mathematical Programming

Reformulation*

Optimize using Classical Technique

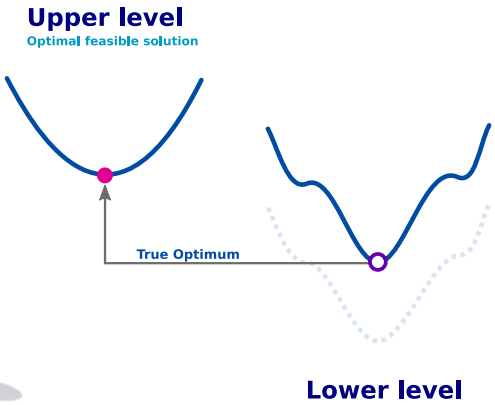
* Very difficult task

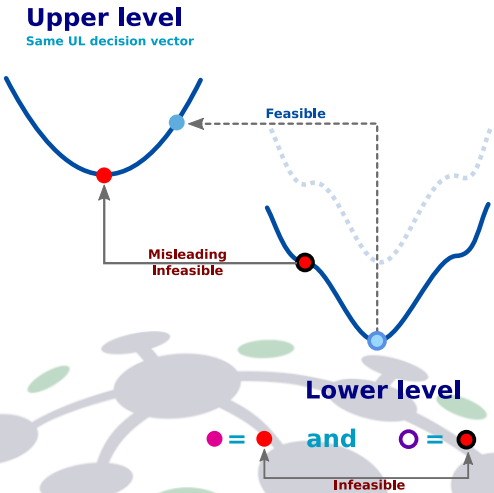
Evolutionary Algorithms



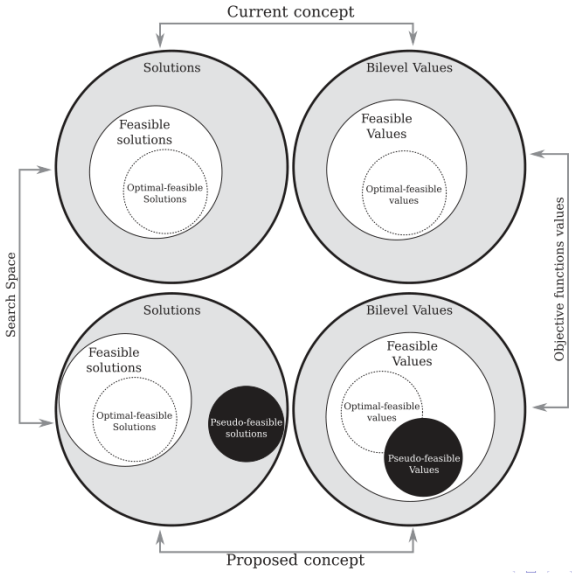
Sinha, A. et al (2017). A review on bilevel optimization: from classical to evolutionary approaches and applications. IEEE Transactions on Evolutionary Computation.

Pseudo-feasible Solutions





Mejía-de-Dios, J. A., Mezura-Montes, E., & Toledo-Hernández, P. (2022). **Pseudo-feasible solutions in evolutionary bilevel optimization: Test problems and performance assessment** . Applied Mathematics and Computation, 412, 126577.


Current concept
Solutions
Feasible solutions
Optimal-feasible Solutions
Bilevel Values
Feasible Values
Optimal-feasible values
Search Space
Objective functions values
Solutions
Feasible solutions
Optimal-feasible Solutions
Pseudo-feasible solutions
Bilevel Values
Feasible Values
Optimal-feasible values
Pseudo-feasible Values
Proposed concept

Evolutionary Bilevel Optimization

Are Evolutionary Algorithms affected by misleading solutions?

Yes, they are.

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	Instance	Misleading	Failed	Success
QBCA-2	PMM1	0%	0%	100%
	PMM2	0%	0%	100%
	PMM3	0%	0%	100%
	PMM4	0%	0%	100%
	PMM5	0%	0%	100%
	PMM6	0%	100%	0%
BLCMAES	PMM1	0%	13%	87%
	PMM2	0%	100%	0%
	PMM3	0%	0%	100%
	PMM4	58%	6%	36%
	PMM5	32%	0%	68%
	PMM6	23%	77%	0%
BLEAQ-2	PMM1	3%	94%	3%
	PMM2	0%	100%	0%
	PMM3	6%	87%	7%
	PMM4	0%	100%	0%
	PMM5	0%	97%	3%
	PMM6	0%	100%	0%

- Theoretical study on existence of misleading solutions.
- Conditions to **mitigate** misleading solutions.
- Test problem construction.
- Performance assessment.

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Conclusions

Final Remarks

- Misleading solutions is a serious issue in evolutionary computation.
- EAs are not robust under presence of pseudo-feasible solutions.
- Unfair comparisons of solutions can be carried out if misleading solutions are no considered as a source of difficulty.

Thanks for your attention!

https://bi-level.org