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Hot Off the Press: Exploring the Explainable Aspects and Performance of a Learnable Evolutionary Multiobjective Optimization Method

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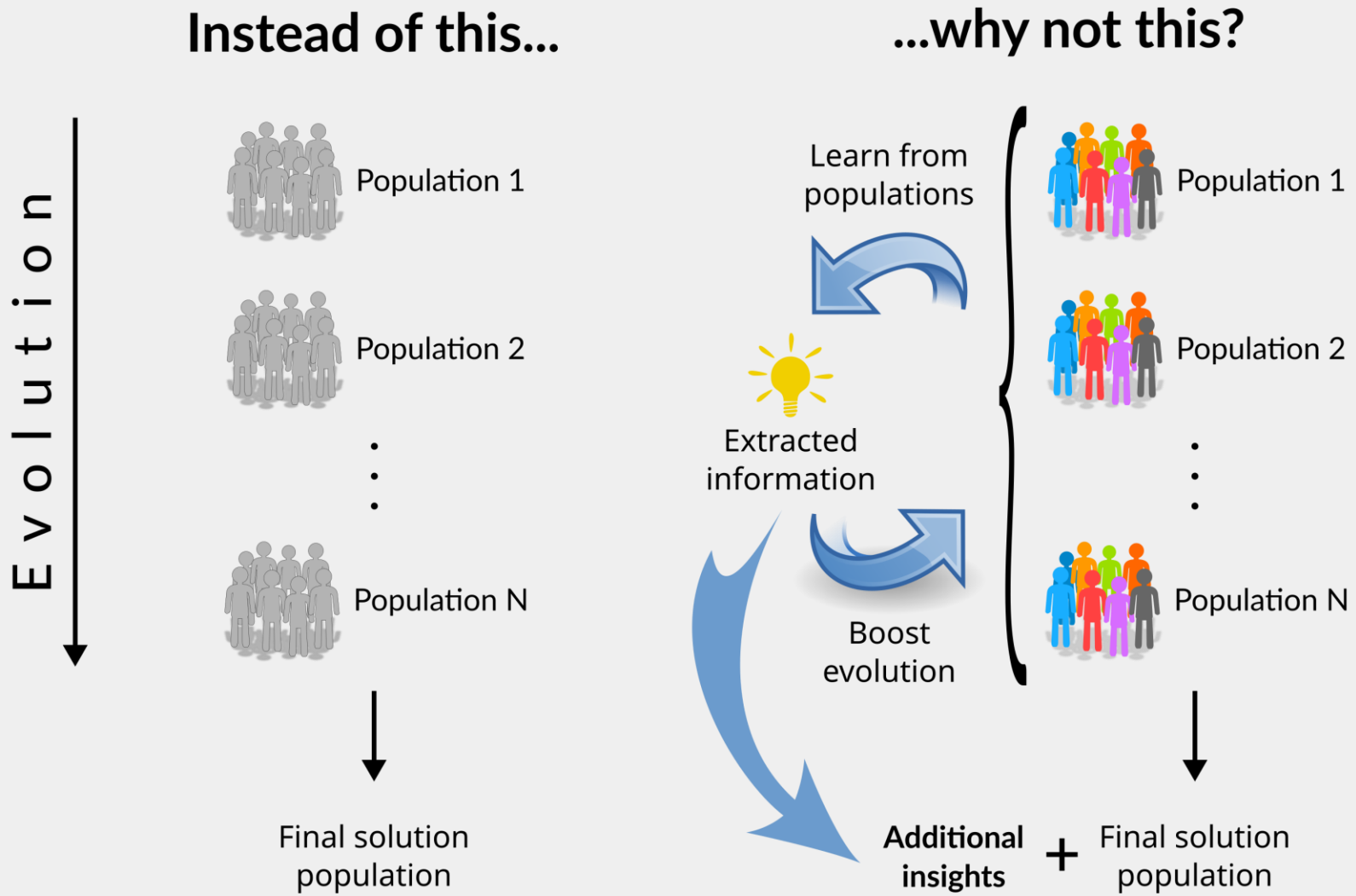
Outline

- Motivation
- Background
- XLEMOO
- Conclusions

Motivation

- Multiobjective optimization methods are tools to support decision-making.
- These tools can help decision makers find solutions to problems with multiple conflicting objective functions and no clear single optimum.
- Evolutionary multiobjective optimization methods can approximate the set of optimal solutions to multiobjective optimization problems.
- In the optimization process, evolutionary methods produce very large populations of solutions, most of which are never used in decisoin-support.

But are we utilizing the generated populations to the fullest?



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Background

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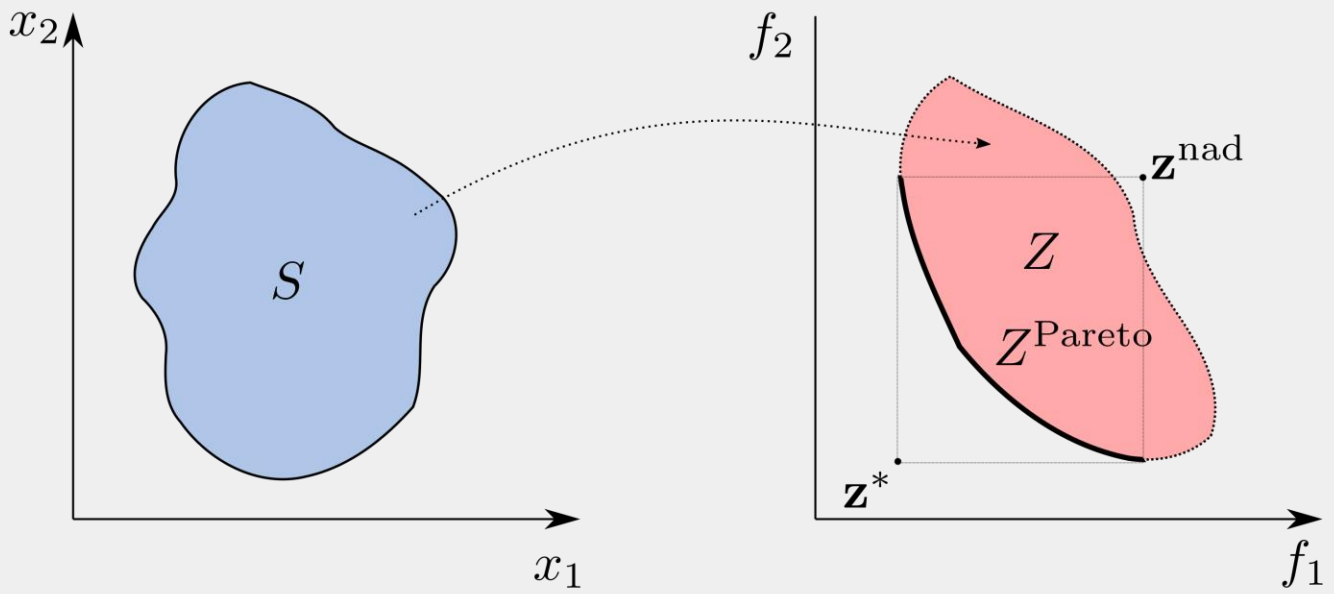
Background: concepts

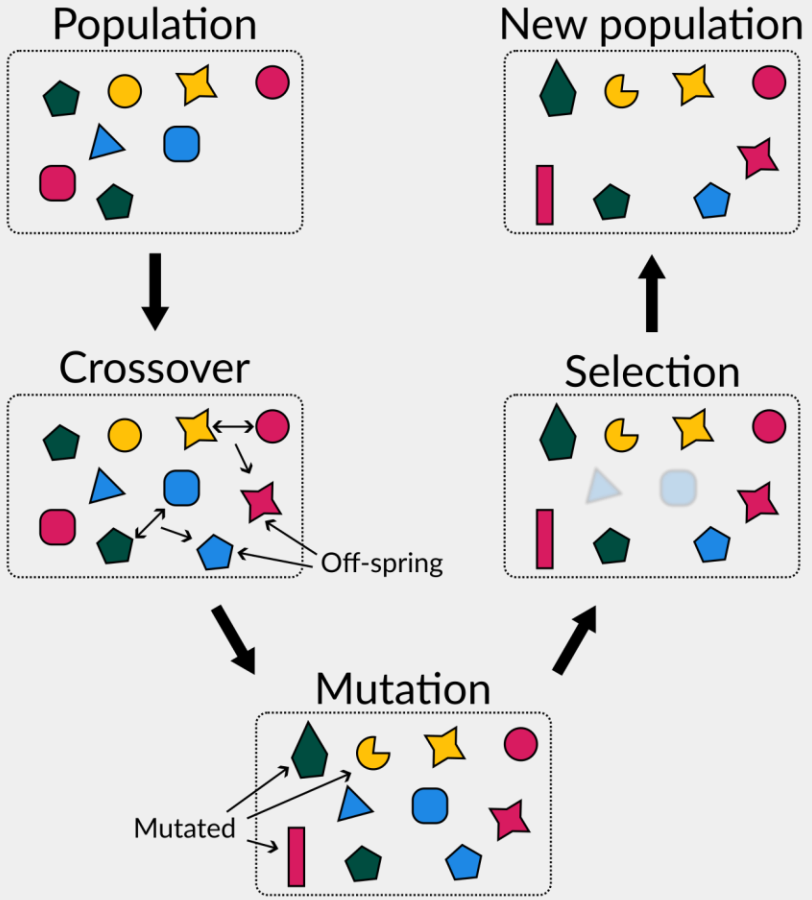
Problem definition

$$\begin{aligned} \text{minimize} \quad & F(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}), \ldots, f_k(\mathbf{x})) \\ \text{s.t.} \quad & \mathbf{x} \in S \end{aligned}$$

Central concepts



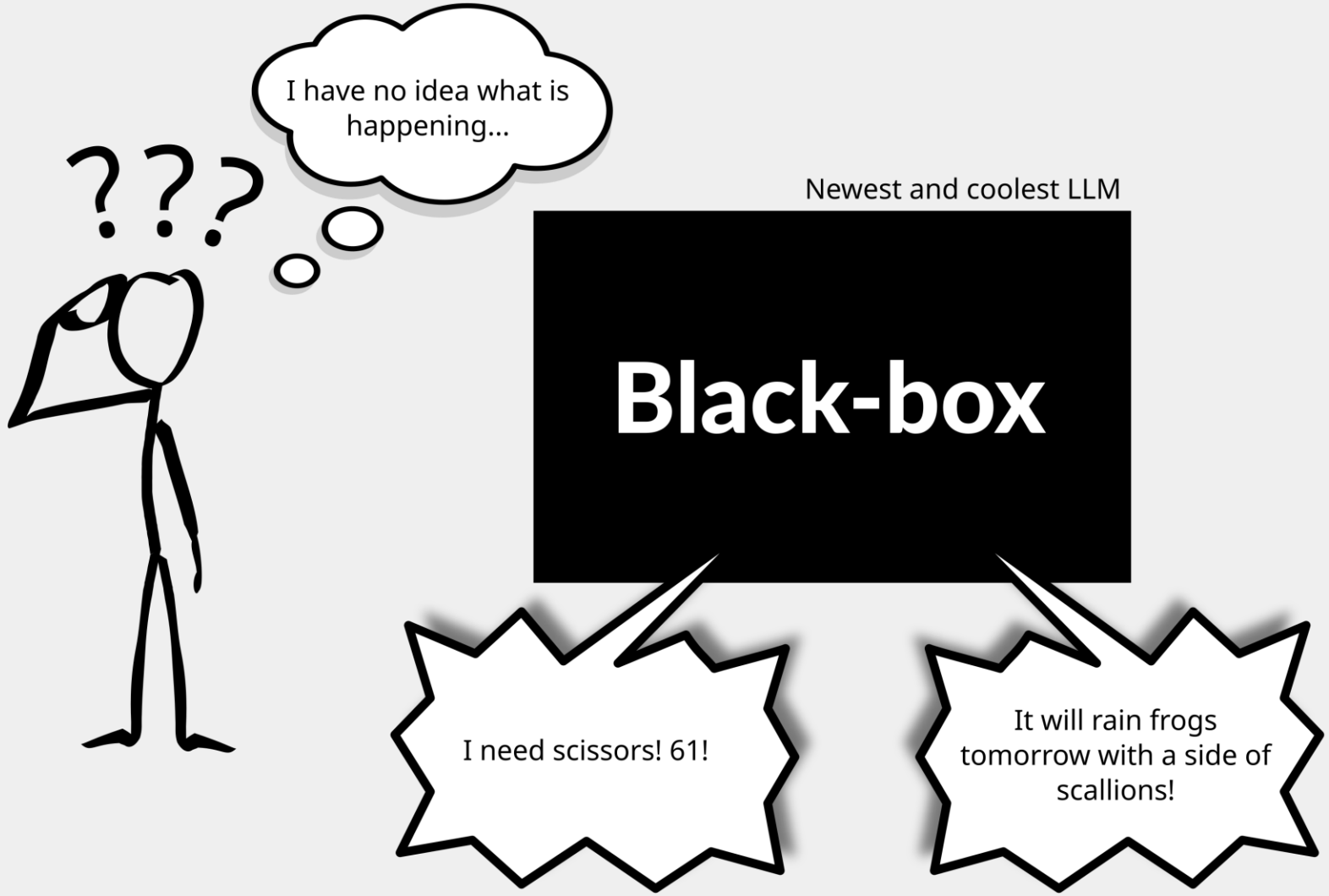
Background: evolutionary methods



Picture courtesy of ChatGPT.

Branke, J., Branke, J., Deb, K., Miettinen, K. & Slowiński, R. (Eds.) 2008. Multiob-ojective optimization: Interactive and evolutionary approaches. Springer.

Background: explainable artificial intelligence



Kamath, U. & Liu, J. 2021. Explainable artificial intelligence: An introduction to interpretable machine learning. Springer.

What about exploring the concept of expainability in evolutionary multiobjective optimization?

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XLEMOO

(Explainable and Learnable Evolutionary Multiobjective Optimization)

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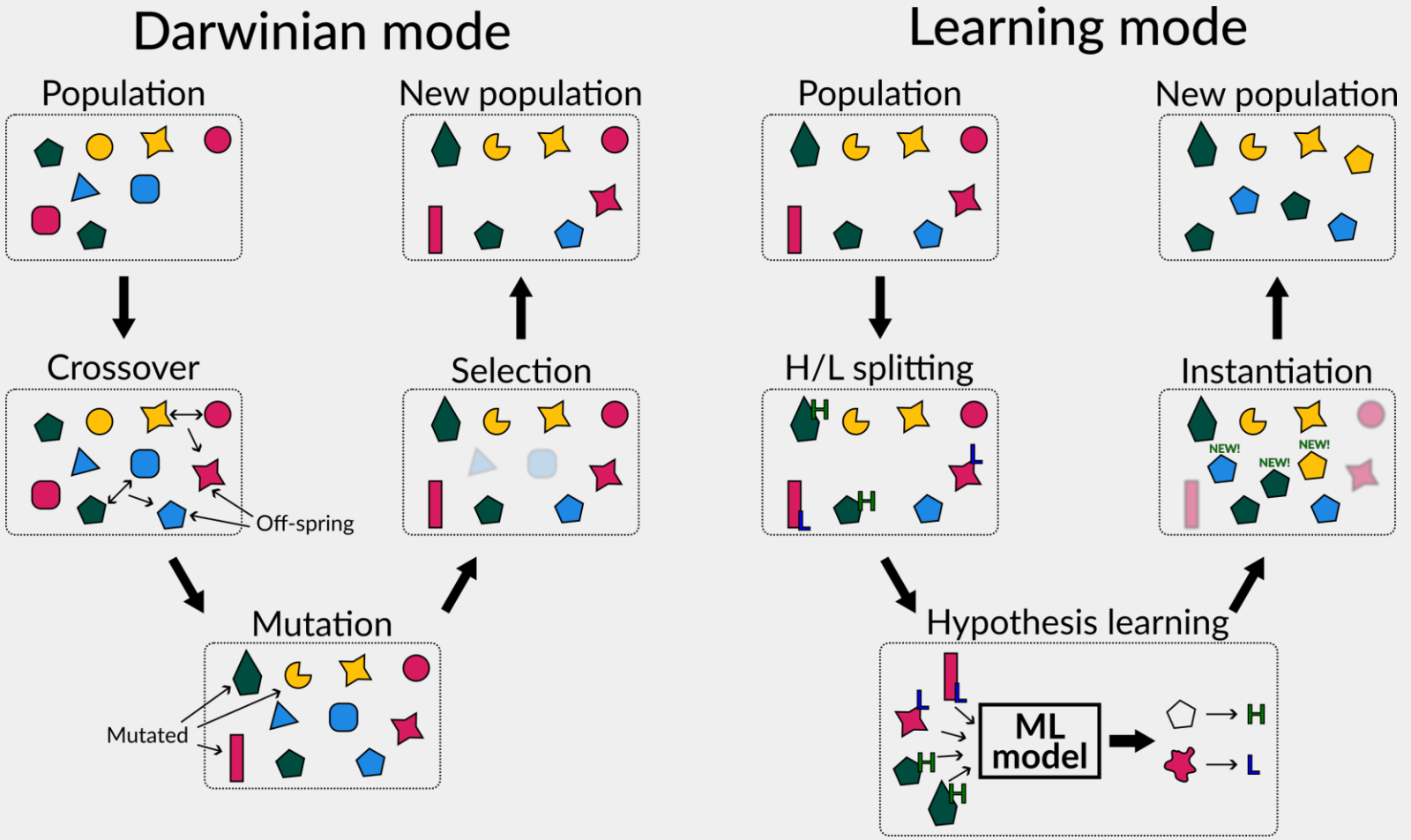
Learnable evolution models



Misitano, G. (2024). Exploring the Explainable Aspects and Performance of a Learnable Evolutionary Multiobjective Optimization Method. *ACM Transactions on Evolutionary Learning*, *4*(1), 1-39.
Michalski, R. S. (2000). Learnable evolution model: Evolutionary processes guided by machine learning. Machine learning, 38, 9-40.

Advantages of learnable evolution models

- Can boost the search process for optimal solutions resulting in less iterations.
- Michalski showed that a learning mode can lead to a "quantum jump" in the fitness of the population.
- **If we use an explainable machine learning model in a learning mode, we could additionally be able to extract new information about the solutions found when solving multiobjective optimization methods!**
- **This new information could be of use to decision makers!**

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The proposed method in a nutshell (the LEMOO method)

- We have implemented a simple indicator-based evolutionary multiobjective optimization method. This is applied in the Darwinian mode.
- As the fitness function, we utilize a scalarization function that incorporates preferences from a decision maker as a reference point.

$$\max_{i=1,\ldots,k}\left[\frac{f_i(\mathbf{x})-\bar{z}_i}{z_i^{\mathrm{nad}}-(z_i^\star-\delta)}\right]+\rho\sum_{i=1}^{k}\frac{f_i(\mathbf{x})}{z_i^{\mathrm{nad}}-(z_i^\star-\delta)}$$

- In a learning mode, we utilize Skope-rules, an explainable machine learning model that generates easy to interpret rule-based models.

RULE 1: IF $a_1 < 8.2$ AND $a_2 > 1.3$ THEN PREDICT 1,
RULE 2: IF $a_1 > 5.5$ AND $a_1 < 6.3$ AND $a_2 < 1.4$ THEN PREDICT 1,
RULE 3: IF $a_2 > 1.1$ THEN PREDICT 1.

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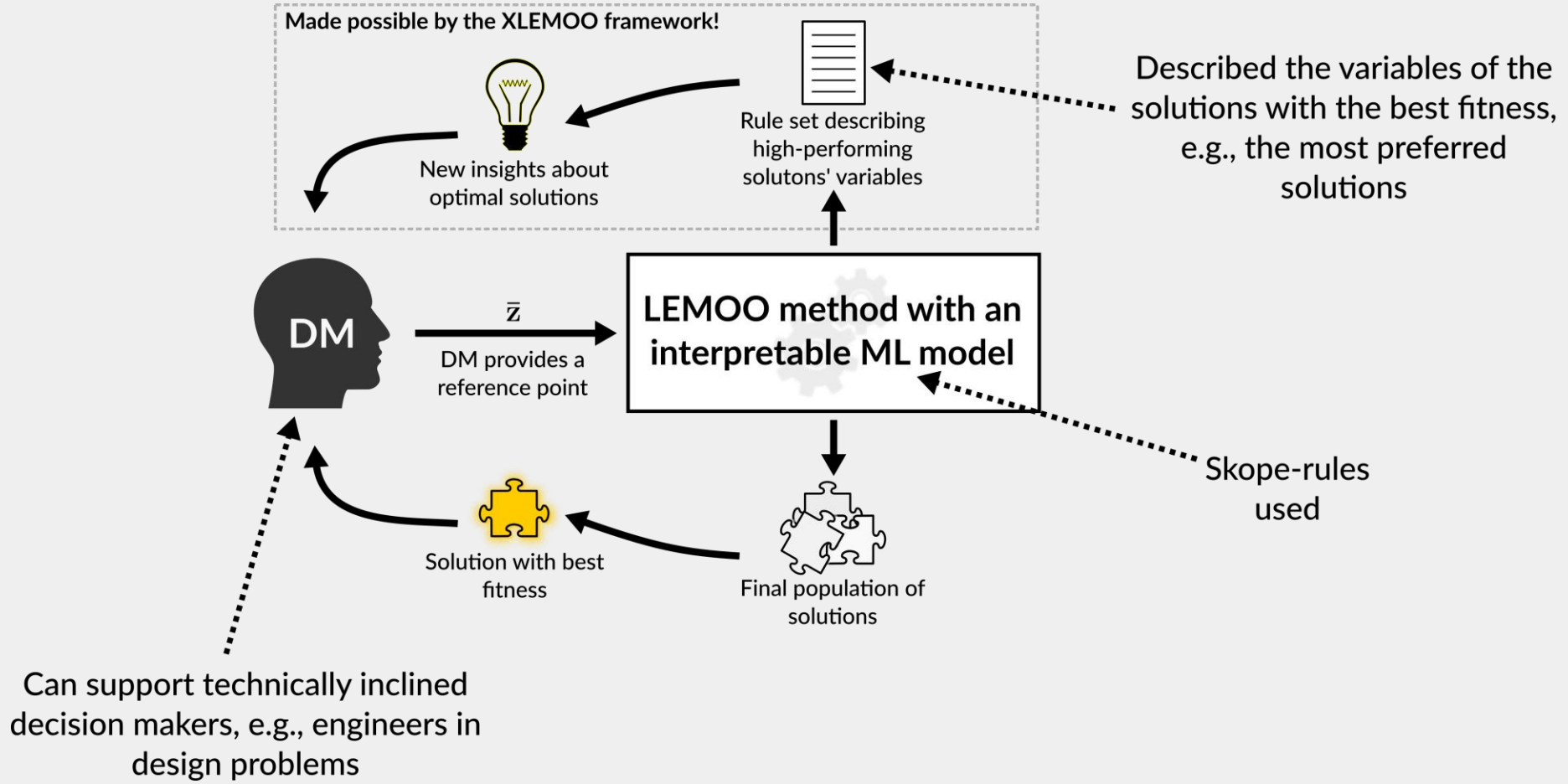
Michalski, R. S. (2000). Learnable evolution model: Evolutionary processes guided by machine learning. Machine learning, 38, 9-40.
Nicolas Goix, Vighnesh Birodkar, Florian Gardin, Jean-Matthieu Schertzer, Hoebin Jeong, Manoj Kumar, Alexandre Gramfort, Tim Staley, Tom Dupré la Tour, Boyuan Deng, C, Fabian Pedregosa, Lawrence Wu, Ariel Rokem, Kyle Jackson, and mrahim. 2020. scikit-learn-contrib/skope-rules v1.0.1. Retrieved October 23, 2023 from https://doi.org/10.5281/zenodo
Zitzler, E., & Künzli, S. (2004, September). Indicator-based selection in multiobjective search. In *International conference on parallel problem solving from nature* (pp. 832-842). Springer.

Describing preferred solutions in a population-based method



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Conclusions

- In our paper, we have shown that introducing a learnable mode to an indicator-based evolutionary multiobjective optimization method can boost the search for optimal solutions. This matches some previous studies.
- We also explored the proposed method in the context of interactive multiobjective optimization, where the explanations generated could support a decision-maker to better understand the results and the possibly even verify the optimization model.
- Further studies needed where explainable machine learning is combined with evolutioary methods in multiobjective optimization.
- The presented work is openly available for anyone to explore and apply to their own needs!

- Check my PhD thesis for further ideas on how explainability can be used to enhance the decision-support capabilities of multiobjective optimization methods: **Misitano, G. (2024). Enhancing the decision-support capabilities of interactive multiobjective optimization with explainability. *JYU Dissertations*.**

To support your endeavors

- DESDEO has played an important supporting role in enabling the works discussed in this presentation.
- DESDEO is currently going through a complete overhaul, which will make it more usable and welcoming to wild new ideas, including explainability.

The Multiobjective Optimization Group

We regularly post about our activities on LinkedIn!

Misitano, G., Saini, B. S., Afsar, B., Shavazipour, B., & Miettinen, K. (2021). DESDEO: The modular and open source framework for interactive multiobjective optimization. *IEEE Access*, *9*, 148277-148295.

Exploring the Explainable Aspects and Performance of a Learnable Evolutionary Multiobjective Optimization Method

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Multiobjective optimization problems have multiple conflicting objective functions to be optimized simultaneously. The solutions to these problems are known as Pareto optimal solutions, which are mathematically incomparable. Thus, a decision maker must be employed to provide preferences to find the most preferred solution. However, decision makers often lack support in providing preferences and insights in exploring the solutions available.

We explore the combination of learnable evolutionary models with interactive indicator-based evolutionary multiobjective optimization to create a learnable evolutionary multiobjective optimization method. Furthermore, we leverage interpretable machine learning to provide decision makers with potential insights about the problem being solved in the form of rule-based explanations. In fact, we show that a learnable evolutionary multiobjective optimization method can offer advantages in the search for solutions to a multiobjective optimization problem. We also provide an open source software framework for other researchers to implement and explore our ideas in their own works.

Our work is a step toward establishing a new paradigm in the field on multiobjective optimization: *explainable and learnable multiobjective optimization*. We take the first steps toward this new research direction and provide other researchers and practitioners with necessary tools and ideas to further contribute to this field.

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https://dl.acm.org/doi/abs/10.1145/3626104