

# DESDEO: the open source framework for interactive multiobjective optimization—recent advancements and future plans

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JYVÄSKYLÄN YLIOPISTO  
UNIVERSITY OF JYVÄSKYLÄ



- I am Giovanni Misitano, a doctoral researcher from the Multiobjective Optimization Group at the University of Jyväskylä.
- I am one of the main developers of DESDEO.
- For more info, visit my homepage:  
<http://giovanni.misitano.xyz>.
- You may also find me on LinkedIn and GitHub (gialmisi).



# In this talk

- 1 Motivation
- 2 Background
- 3 DESDEO
  - Core packages
  - Beyond the core packages
- 4 Recent advancements
  - The web API
  - User interface: Problem definition
- 5 Going forward
  - Minimum viable product
  - Future steps
- 6 How to get started?

- 1 Motivation
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# Current state of affairs

- Multiobjective optimization problems have many, often mathematically incomparable optimal solutions.
- The *best* solution is subjective and depends on the preferences of the *decision maker*.
- We lack proper software and tools to support decision-making and decision makers in *interactive multiobjective optimization*.



# We need software!

- We propose DESDEO to tackle this lack of software plaguing especially interactive multiobjective optimization.
- We will learn more about DESDEO soon!

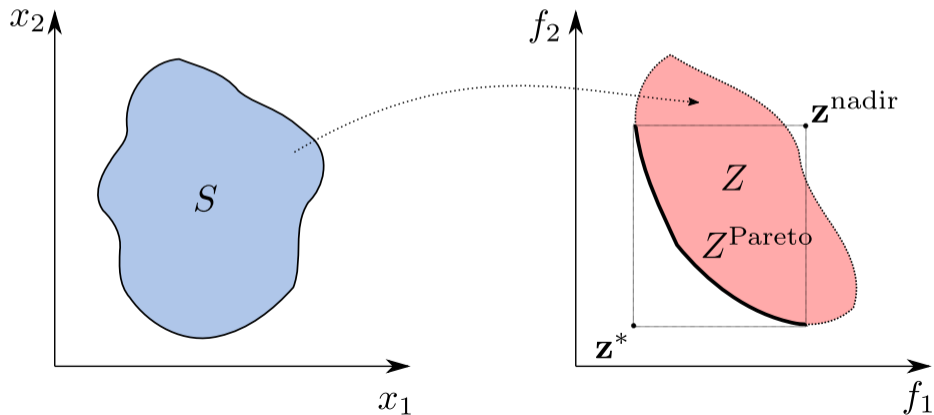


# Background

- 1 Motivation
- 2 Background**
- 3 DESDEO
  - Core packages
  - Beyond the core packages
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  - The web API
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  - Minimum viable product
  - Future steps
- 6 How to get started?

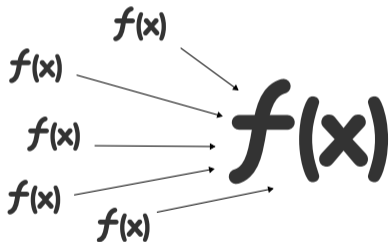
# Multiobjective optimization problems

$$\min_{\mathbf{x} \in S} \mathbf{f}(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}))$$

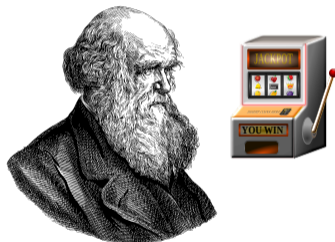




## Scalarization

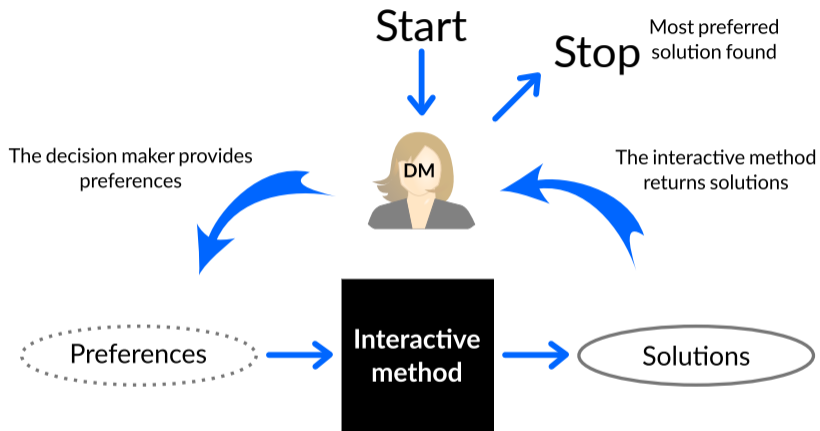


## Evolutionary



...and others as well!

# Interactive multiobjective optimization



- 1 Motivation
- 2 Background
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- DESDEO<sup>1</sup> is a modular and open source Python framework for interactive multiobjective optimization.
- DESDEO's *core packages* provide the algorithms and computational resources for interactive multiobjective optimization.
- Contains also packages for a web API (application programming interface) and web-based user interface.

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<sup>1</sup>G. Misitano, B. S. Saini, B. Afsar, B. Shavazipour, and K. Miettinen. "DESDEO: The Modular and Open Source Framework for Interactive Multiobjective Optimization". *IEEE Access* 9 (2021), pp. 148277–148295. DOI: [10.1109/ACCESS.2021.3123825](https://doi.org/10.1109/ACCESS.2021.3123825).

# Why DESDEO?

- To have multiple interactive methods of various types under the same framework.
- To ease switching between different interactive methods.
- To ease the comparison of interactive methods.
- To have a documented framework.
- To ease experimenting with and applying different interactive methods.
- And more!

# Compared to some existing software

Name	Programming language	MO focus	Method type		Decision making	Interactive methods	Visualization	UI	Modularity
			EMO	MCDM					
ine DEAP	<i>Python</i>								✓
Inspyred	<i>Python</i>								✓
vOptSolver	<i>Julia</i>	✓		✓					
Platypus	<i>Python</i>	✓	✓			✓			✓
MOEA	<i>Java</i>	✓	✓			✓			✓
PaGMO/PyGMO	<i>C++/Python</i>	✓	✓			✓			✓
jMetal/jMetalPy	<i>Java/Python</i>	✓	✓		✓	✓			✓
Pymoo	<i>Python</i>	✓	✓		✓	✓			✓
PlatEMO	<i>Matlab</i>	✓	✓		✓	✓		✓	✓
<b>DESDEO</b>	<i>Python</i>	✓	✓	✓	✓	✓	(✓)	(✓)	✓

Figure: From the DESDEO paper<sup>2</sup>.

<sup>2</sup>G. Misitano, B. S. Saini, B. Afsar, B. Shavazipour, and K. Miettinen. "DESDEO: The Modular and Open Source Framework for Interactive Multiobjective Optimization". *IEEE Access* 9 (2021), pp. 148277–148295. DOI: 10.1109/ACCESS.2021.3123825.

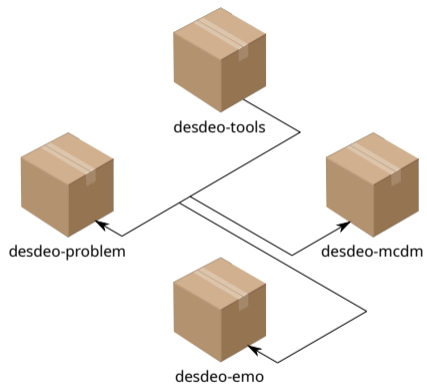
# Hybridization

- Scalarization-based methods can compute accurate Pareto optimal solutions, but only one at a time.
- Evolutionary methods can compute multiple solutions simultaneously, but their Pareto optimality cannot be guaranteed.



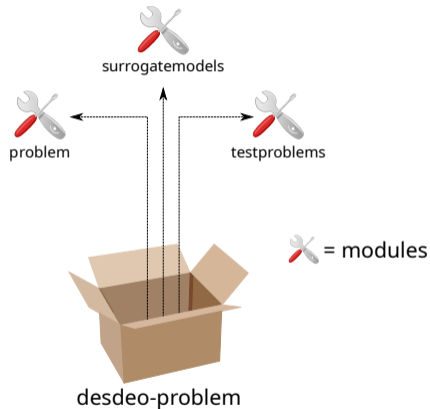
- Hybridization: use an evolutionary method for a rough search and polish the result utilizing a scalarization-based method.

# Core packages

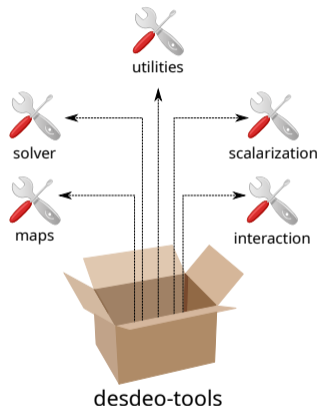




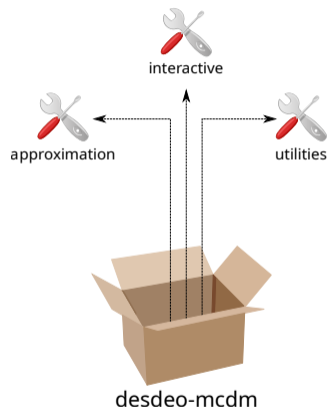
- Tools and utilities to model multiobjective optimization problems.
- Various pre-defined test problems.
- Tools to model problems based on data, i.e., surrogate models.



- (interfaces to) Single-objective optimization solvers.
- Tools to scalarize multiobjective optimization problems.
- Tools to facilitate interaction between a decision maker and an interactive method.
- Various mappings to transform multiobjective optimization problems.
- Other miscellaneous tools, e.g., routines to compute ideal and nadir points.



- Scalarization-based interactive methods, including trade-off free methods and navigation methods.
- Methods to approximate the Pareto optimal front.
- Various utilities needed in scalarization-based methods.



Some examples of interactive methods implemented in `desdeo-mcdm` include:

- Synchronous NIMBUS<sup>3</sup>,
- E-NAUTILUS<sup>4</sup>,
- NAUTILUS Navigator<sup>5</sup>, and
- The Reference Point Method<sup>6</sup>.

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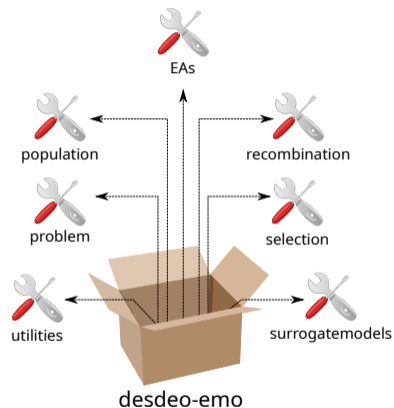
<sup>3</sup>Kaisa Miettinen and Marko M. Mäkelä. "Synchronous approach in interactive multiobjective optimization". *European Journal of Operational Research* 170.3 (2006), pp. 909–922. DOI: [10.1016/j.ejor.2004.07.052](https://doi.org/10.1016/j.ejor.2004.07.052).

<sup>4</sup>Ana B. Ruiz, Karthik Sindhya, Kaisa Miettinen, Francisco Ruiz, and Mariano Luque. "E-NAUTILUS: A decision support system for complex multiobjective optimization problems based on the NAUTILUS method". *European Journal of Operational Research* 246.1 (2015), pp. 218–231. DOI: [10.1016/j.ejor.2015.04.027](https://doi.org/10.1016/j.ejor.2015.04.027).

<sup>5</sup>Ana B. Ruiz, Francisco Ruiz, Kaisa Miettinen, Laura Delgado-Antequera, and Vesa Ojalehto. "NAUTILUS Navigator: free search interactive multiobjective optimization without trading-off". *Journal of Global Optimization* 74.2 (2019), pp. 213–231. DOI: [10.1007/s10898-019-00765-2](https://doi.org/10.1007/s10898-019-00765-2). URL: <https://doi.org/10.1007/s10898-019-00765-2>.

<sup>6</sup>Andrzej P Wierzbicki. "A mathematical basis for satisficing decision making". *Mathematical Modelling* 3 (1982), pp. 391–405.

- Evolutionary algorithms and operators to implement interactive methods.
- Tools to model populations for evolutionary algorithms.
- Surrogate models specific to evolutionary methods.
- Various utilities needed in evolutionary interactive methods.



- Some examples of interactive methods implemented in desdeo-emo include:
  - PBEA<sup>7</sup>, MOEA/D<sup>8</sup>, interactive RVEA<sup>9</sup>, interactive NSGA-III<sup>10</sup>, and an implementation of the PIS<sup>11</sup> paradigm.
- For how RVEA and NSGA-III have been made interactive, see<sup>12</sup>.

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<sup>7</sup>Lothar Thiele, Kaisa Miettinen, Pekka J Korhonen, and Julian Molina. "A preference-based evolutionary algorithm for multi-objective optimization". *Evolutionary computation* 17.3 (2009), pp. 411–436.

<sup>8</sup>Qingfu Zhang and Hui Li. "MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition". *IEEE Transactions on Evolutionary Computation* 11.6 (2007), pp. 712–731. DOI: 10.1109/TEVC.2007.892759.

<sup>9</sup>Ran Cheng, Yaochu Jin, Markus Olhofer, and Bernhard Sendhoff. "A Reference Vector Guided Evolutionary Algorithm for Many-Objective Optimization". *IEEE Transactions on Evolutionary Computation* 20.5 (2016), pp. 773–791. DOI: 10.1109/TEVC.2016.2519378.

<sup>10</sup>Kalyanmoy Deb and Himanshu Jain. "An Evolutionary Many-Objective Optimization Algorithm Using Reference-Point-Based Nondominated Sorting Approach, Part I: Solving Problems With Box Constraints". *IEEE Transactions on Evolutionary Computation* 18.4 (2014), pp. 577–601. DOI: 10.1109/TEVC.2013.2281535.

<sup>11</sup>Bhupinder Singh Saini, Jussi Hakanen, and Kaisa Miettinen. "A New Paradigm in Interactive Evolutionary Multiobjective Optimization". *Parallel Problem Solving from Nature – PPSN XVI*. ed. by Thomas Bäck, Mike Preuss, André Deutz, Hao Wang, Carola Doerr, Michael Emmerich, and Heike Trautmann. Cham: Springer International Publishing, 2020, pp. 243–256.

<sup>12</sup>Jussi Hakanen, Tinkle Chugh, Karthik Sindhya, Yaochu Jin, and Kaisa Miettinen. "Connections of reference vectors and different types of preference information in interactive multiobjective evolutionary algorithms". *2016 IEEE Symposium Series on Computational Intelligence (SSCI)*. Athens, Greece: IEEE, 2016, pp. 1–8. DOI: 10.1109/SSCI.2016.7850220.

- Core packages alone are not enough.
- We also need a modular framework for building user interfaces<sup>13</sup>.
- Interactive methods require unique visualizations.

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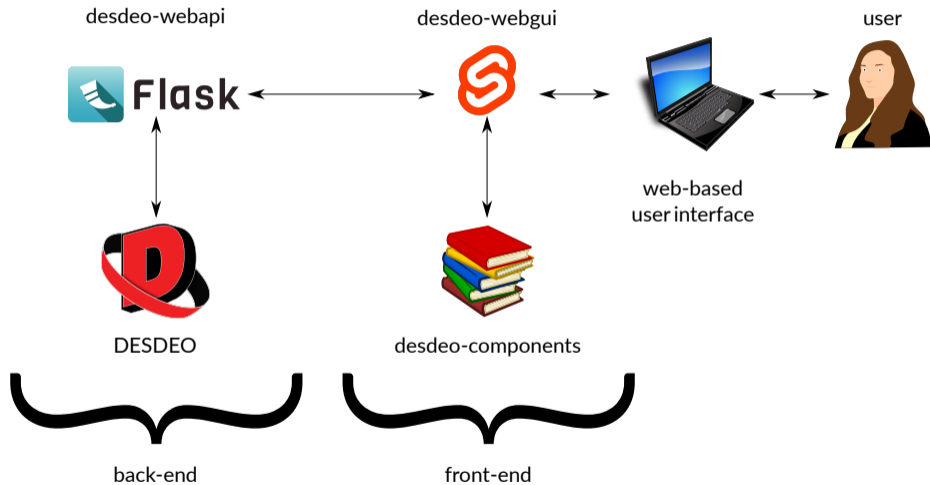
<sup>13</sup>Giomara Lárraga and Kaisa Miettinen. "Component-Based Thinking in Designing Interactive Multiobjective Evolutionary Methods". *Proceedings of the Companion Conference on Genetic and Evolutionary Computation. GECCO '23 Companion*. Lisbon, Portugal: Association for Computing Machinery, 2023, pp. 1693–1702. DOI: 10.1145/3583133.3596307.

# Recent advancements

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- 2 Background
- 3 DESDEO
  - Core packages
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# The DESDEO ecosystem



# The web API (application programming interface)

- Allow utilizing the core packages from (almost) any software.
- User registration, session management, saving problems and solutions, and much more. . .
- Enables utilization of a proper database<sup>14</sup>.

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<sup>14</sup>Bhupinder Singh Saini, Giomara Lárraga, and Kaisa Miettinen. "Using a Database to Support Interactive Multiobjective Optimization, Visualization, and Analysis". *Proceedings of the Companion Conference on Genetic and Evolutionary Computation. GECCO '23 Companion*. Lisbon, Portugal: Association for Computing Machinery, 2023, pp. 1703–1711. doi: 10.1145/3583133.3596383.

- Web-based interfaces offer good accessibility—user has no need to install anything locally.
- Many options and choices, especially when it comes to the visualization and display of information.
- Extensible and customizable by developers as well.

# User interface: Problem definition

Logged in as a guest / [Log out](#)

The screenshot shows a web interface for defining optimization problems. On the left is a dark sidebar with a red circle containing a white 'D', a 'Saved problems' section with a folder icon, and a 'New problem' section with a plus sign. The main content area has a light gray background. At the top left of this area is the heading 'Enter a new problem'. Below it is a paragraph explaining the interface's purpose and a note about data validation. A 'General instructions' link with a question mark icon is present. Below that are two buttons: 'Save to file' (with a download icon) and 'Clear all'. Further down are four categories: 'Variables', 'Objectives', 'Constraints', and 'Constants', each with a question mark icon and a '+ New' button.

**Enter a new problem**

This interface can be used to enter a new multiobjective optimization problem and download it in a JSON format understood by the [desdeo-problem](#) library.

Note that this interface can't fully validate the entered data. You'll need to follow the instructions to make sure that [desdeo-problem](#) will accept the problem.

General instructions: [?](#)

[Save to file](#) [Clear all](#)

Variables [Objectives](#) [Constraints](#) [Constants](#)

+ New + New + New + New

[How to cite DESDEO?](#)

# User interface: Problem definition

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General instructions: [?](#)

[Save to file](#) [Clear all](#)

### Variables [?](#)

Continuous  Discrete  Binary  
Description\*

Continuous  Discrete  Binary  
Description\*

[+ New](#)

### Objectives [?](#)

=   
Description\*

[+ New](#)

### Constraints [?](#)

≥   
g\_1  
Description\*

[+ New](#)

### Constants [?](#)

[+ New](#)

[How to cite DESDEO?](#)

# User interface: Pre-defined problems

D  
Saved problems  
+  
New problem

Logged in as a guest / [Log out](#)

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1. Select a problem    3. Solve the problem

Please select a problem. Then [continue to selecting a solution method](#).

Your saved problems    Problems provided by DESDEO

Name	Objectives	Variables	Constraints
car_side_impact	3	7	10
vehicle_crash_worthiness	3	5	-
river_pollution_w_ideal_and_nadir	5	2	-

### Problem details

Name: river\_pollution\_w\_ideal\_and\_nadir

Objectives:

Name	Minimize
the DO level in the city	true
the DO level at the municipality border	true
the percent return on investment at the fishery	true
the addition to the tax rate of city	true
BOD removed form the water close to the ideal value of 0.65	true

Variables:

Name
the proportionate amount of BOD removed from water at the fishery
the proportionate amount of BOD removed from water at the city

[How to cite DESDEO?](#)

# User interface: The reference point method

Logged in as a guest / [Log out](#)

1. Select a problem
3. Solve the problem

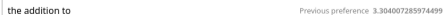
## Reference point method

Please select a reference point and then click "iterate".

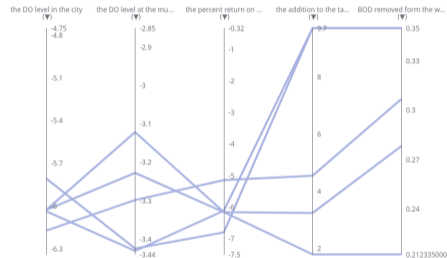
Iterate

### Preference information

Please select an aspiration level for each of the objectives using the horizontal bar or the input box. The input box can be used to enter a value outside the range of the horizontal bar.

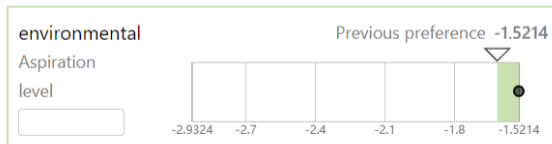
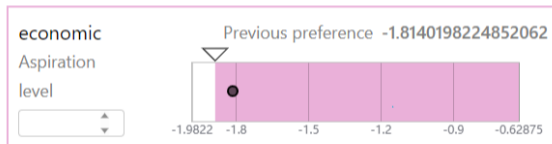
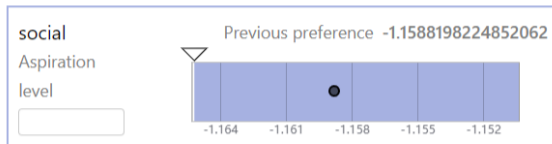


## Solutions



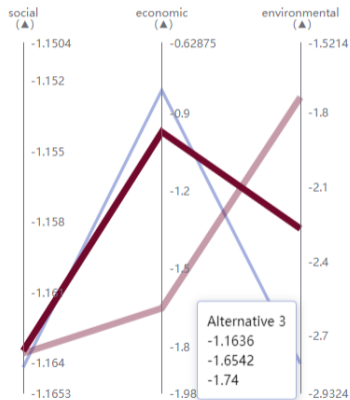
How to cite DESDEO?

# Visualizations: Horizontal bars

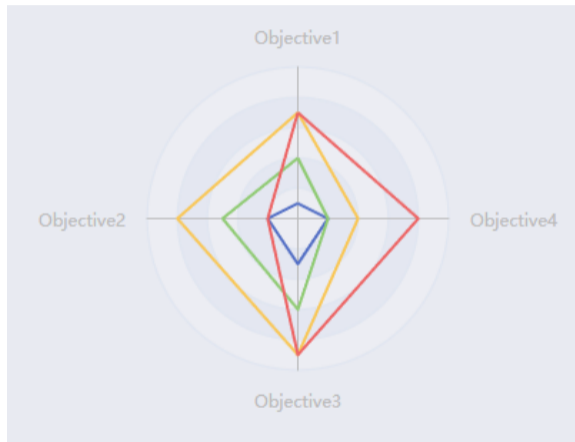




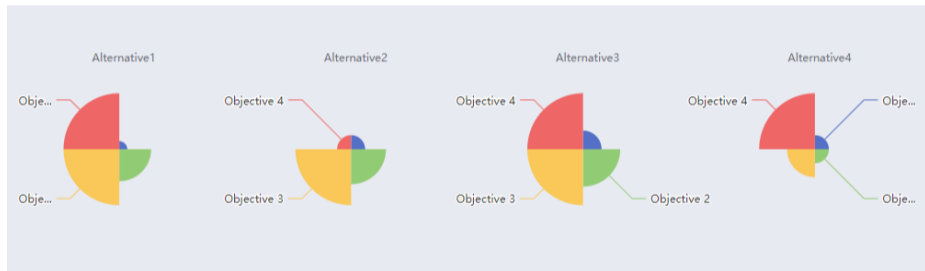
## Solutions



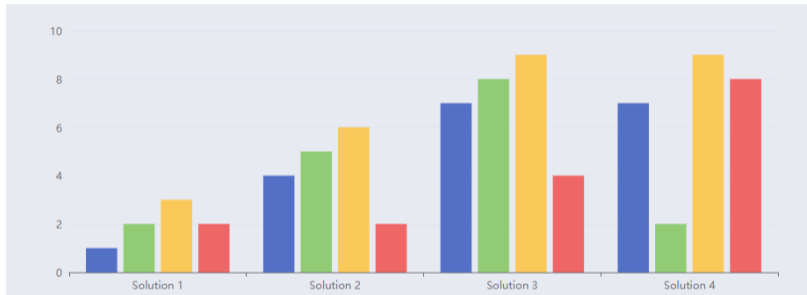
# Visualizations: Spider plot



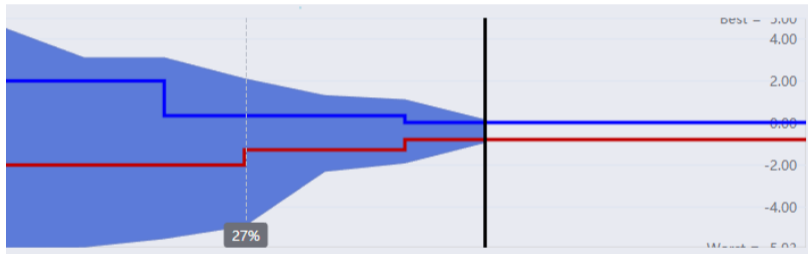
# Visualizations: Petal diagram



# Visualizations: Bar plot



# Visualizations: Navigation bar



# Going forward

- 1 Motivation
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  - Core packages
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By the end of August, DESDEO will have:

- support for mixed-integer problems,
- a modern and modular web-based user interface,
- interfaces for different interactive methods (both scalarization-based and evolutionary),
- a database to store problems, solutions, and other data;
- enhanced documentation,
- support for guest users (to let people quickly try out DESDEO with test problems),
- and more!

We have four summer trainees working tirelessly on delivering the minimum viable product this summer. Thanks to (in no particular order):

- Yan Shenheng,
- Eduard Ciriaco,
- Runo–Mikael Ojala, and
- Severi Nättilä!



- Development of DESDEO will continue actively right after the minimum viable product.
- Some of the focal points going forward:
  - group decision-making,
  - scenarios and deep uncertainty,
  - explanations and their visualization,
  - better hybridization and switching of methods,
  - and more!

# How to get started?

- 1 Motivation
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- Download DESDEO and check the notebooks for examples.
- Utilize or combine existing methods, or both.
- To understand how DESDEO and its interactive methods work, the DESDEO paper has good examples<sup>15</sup>.

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<sup>15</sup>G. Misitano, B. S. Saini, B. Afsar, B. Shavazipour, and K. Miettinen. "DESDEO: The Modular and Open Source Framework for Interactive Multiobjective Optimization". *IEEE Access* 9 (2021), pp. 148277–148295. DOI: [10.1109/ACCESS.2021.3123825](https://doi.org/10.1109/ACCESS.2021.3123825).

- Anybody is welcome to contribute!
- Make changes and create a pull request. Or just open new issues on GitHub.
- Use DESDEO as a platform to publish your work!

- DESDEO's homepage: <https://desdeo.it.jyu.fi/>
- DESDEO on GitHub: <https://github.com/industrial-optimization-group>
- YouTube videos: <https://www.youtube.com/@mopgroup6817>

- DESDEO is free to use and modifiable by anyone!
- Consider utilizing DESDEO in your future multiobjective optimization endeavors.
- Consider contributing to DESDEO.

Thank you! Questions?



<https://desdeo.it.jyu.fi/media/EUROPT23.pdf>