MSc. thesis topics
Multiobjective Optimization Group

Many decision-making problems arising from real-world applications can be expressed as multiobjective optimization problems, where several, typically conflicting, perspectives need to be considered simultaneously. All these MSc thesis topics are related to supporting decision making with multiobjective optimization. Decision supporting skills are needed in practically all fields of life and, thus, completing a MSc thesis based on any of these topics increases your employability in the industry and offers an opportunity to pursue an academic career as well, if you so wish.

If you find any of the topics listed in this document interesting or want to know more, please contact one of the supervisors listed at the beginning of each topic. The emails of these members of the Multiobjective Optimization Group are in Table 1. Note that many of the topics have a lot of possibilities to customize the topic to better meet your own interests. The list of topics is directional.

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Table 1: Contact information of the supervisors.

Collaboration: possibility to collaborate with the DAEMON project and companies as a member of the Multiobjective Optimization Group (http://www.mit.jyu.fi/optgroup/)
Language options for supervision and completing the thesis: English (all supervisors) or Finnish (Kaisa Miettinen, Johanna Silvennoinen, Giovanni Misitano)
Requirements: If the focus is on software development, programming skills are required (object-oriented programming), if on empirical studies, experience in conducting empirical research is beneficial. For method development a strong mathematical/statistical background is beneficial.

Introduction

When making decisions, the decision maker must typically balance among multiple conflicting perspectives. Simultaneous optimization of multiple conflicting objectives is known as multiobjective optimization. These problems have so-called Pareto optimal solutions (or compromises) representing

different trade-offs and to find the best solution, it is necessary to involve a domain expert, known as a decision maker (DM), whose knowledge and preferences can be used to find preferred solution(s).

Based on how preferences are incorporated in the solution process, multiobjective optimization methods can be divided into different categories. In interactive methods, the DM takes actively part in the solution process and preferences are incorporated during the optimization process. This has many advantages. For instance, interactive methods can focus on a particular subset of the Pareto optimal solutions that is interesting to the DM. This does not only save in computation costs, but also allows the DM to focus on solutions that best meet their current preferences.

The DESDEO framework (desdeo.it.jyu.fi) is an open source Python framework for interactive multiobjective optimization developed in the Multiobjective Optimization research group. DESDEO contains some interactive methods, which are implemented in a modular fashion. This allows reusing existing components when developing new methods. Most new methods are expected to be implemented as part of DESDEO as open source software.

I- New methods for decision making

Topic 1: How to support the decision maker in switching between interactive methods? (Kaisa Miettinen, Bekir Afsar, Johanna Silvennoinen, Pouya Aghaei pour and Bhupinder Singh Saini)

In interactive methods, the DM directs the solution process to find the most preferred solution. We can divide the solution process into two phases: learning and decision phases. During the learning phase, the DM explores different solutions to identify a region of interest. In the decision phase, the DM finds the most preferred solution by fine-tuning the search in the region of interest. Some interactive methods support the DM better during the learning phase, whereas others are better at exploiting the region of interest. Typically, only one interactive method is selected and applied in the solution process, and the type of preference information is specific to the method used. However, switching the method during the solution process can offer benefits. In this thesis, you will investigate approaches for switching interactive methods based on the DM's needs and preferred preference styles in different phases.

In other words, you find ways to enable the DM to switch the method (and the type of preference information) during the solution process. You will implement the mechanism you proposed as a part of the DESDEO framework (desdeo.it.jyu.fi).

Required skills

Prior experience in multiobjective optimization is desired. You should also be proficient in Python and Linux environments.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support and interactive multiobjective optimization will increase significantly. You may also refine your findings as a conference or journal paper, if you like.

Examples of tasks in this topic

- Studying literature to understand the need to switch between interactive methods during the solution process.
- Identifying challenges (what are needed) in switching between interactive methods.
- Implementing approaches enabling switching between interactive methods based on the preferred way of providing preferences by the DM during the solution process.

Topic 2: Navigation methods for multiobjective optimization: making a synthesis and implementing contents to DESDEO (Kaisa Miettinen and Giovanni Misitano)

A particular class of interactive multiobjective optimization methods is navigation methods. In these methods, the DM can see in real-time how preferences affect the solution process, what kind of solutions are available, and what kind of solutions could become available with different preferences. An example of a navigation method is NAUTILUS Navigator, which is show-cased in the following video: https://www.youtube.com/watch?v=gjvIG8PiPBo

In this thesis, you will explore the existing literature in multiobjective optimization for navigation-based methods. Particularly, you will be making a synthesis of these methods. This sort of synthesis, if done well, can be readily made into an article leading to a scientific publication. You will also have the option to implement navigation-based method in the DESDEO framework. Thus, you can have a more methodological or implementational focus.

Required skills

Prior experience in multiobjective optimization is desired. You should also be proficient in Python and Linux environments if you choose to also implement a navigation-based method in DESDEO.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support and interactive multiobjective optimization will increase significantly. You may also expect your master's thesis to be eligible to be extended into a conference or journal article.

Examples of tasks in this topic

- Performing a literature study on existing navigation-based methods in multiobjective optimization.
- Synthetization of some of the existing methods, possibly creating a new navigation-based method.
- Implementing your synthesis, possibly alongside other navigation-based methods, in DESDEO as open source software.

Topic 3: Ways to utilize PAINT (PAreto front INTerpolation): dealing with computationally expensive problems (Kaisa Miettinen, Babooshka Shavazipour and Giovanni Misitano)

The PAINT (PAreto front INTerpolation) method [1] is aimed at solving computationally expensive multiobjective optimization problems, where function evaluations are time-consuming (e.g., based on simulations). PAINT formulates a computationally inexpensive surrogate problem to replace the original

one so that the Pareto optimal solutions of the surrogate problem approximate those of the original one. In practice, the method interpolates between a given set of Pareto optimal solutions to derive a mixed integer linear surrogate problem which can be solved with any interactive method to yield a preferred solution for the original problem in a faster way.

In this thesis, you will explore the existing literature on approximation methods (literature review) and the implementation of the PAINT method in the DESDEO framework to connect PAINT to the functionalities of DESDEO. Your thesis can also consist of a real-life case study using PAINT to approximate the Pareto optimal solutions and solve the problem with an interactive method. In this case, you may contribute to the literature that can lead to a scientific publication.

Required skills

Prior knowledge of multiobjective optimization is desired. You should also be proficient in Python. Prior background in mathematics (approximation methods and numerical analysis) is also beneficial.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support in general and in interactive multiobjective optimization and approximation methods for handling computationally expensive problems will increase significantly, and you can make significant contributions to open source software development.

Examples of tasks in this topic

- Accomplishing a literature review on approximation methods for multiobjective optimization.
- Implementing (coding) the PAINT method in the DESDEO framework.
- Conducting a real-life case study using PAINT (your implementation) to approximate the Pareto optimal solutions and solve the problem with an interactive method. Otherwise, you can show the applicability of your implemented version in a hypothetical example (e.g., from literature).

[1] Hartikainen, M., Miettinen, K., & Wiecek, M. M. (2012). PAINT: Pareto front interpolation for nonlinear multiobjective optimization. Computational optimization and applications, 52(3), 845-867.

II- Artificial Intelligence in decision making

Topic 4: Smart evolutionary algorithms for multiobjective optimization (Pouya Aghaei pour)

The use of evolutionary algorithms to solve real-world optimization problems has been getting increasing attention. Typically, evolutionary algorithms have several parameters that needs to be set according to each problem. However, setting the right values for these parameters is a challenging task and sometimes we do not even know the effect of these parameters on the performance of the algorithm for a specific problem very well.

In this thesis, you will work closely with different types of evolutionary methods and come up with an AI method to analyze each method and the problem to be solved in order to set those parameters. Moreover, the model will learn to fine tune these parameters during the solution process so that we can

maximize the performance of the algorithms. Obviously, in case the results are promising, there is an option to write a scientific paper and publish it. Also, you will have the option to be part of our software development team and implement your method in the DESDEO framework.

Required skills

Expertise in Python, basics of multiobjective optimization or willingness to learn, algorithmic thinking and familiarity with basic concepts of machine learning.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in artificial intelligence and algorithm development will increase significantly. You may also expect your master's thesis to be eligible to be extended into a conference or journal article.

- Examples of tasks in this topic Learning more about evolutionary multiobjective optimization methods and how to modify them to be applicable to real-world problems.
- Exploring different ways of making evolutionary methods self-adaptive based on the problem that is being solved.
- Building and training AI models that explore different aspects of multiobjective optimization problems being solved and making a connection between the problem domain and the parameters of the evolutionary algorithms to increase the algorithms' performance.

Topic 5: Modeling decision maker's preferences with BDI agents (Bekir Afsar and Giovanni Misitano)

Eliciting and modeling the preferences of a DM is a challenging task. Many methods exist to accomplish this. However, they often leave much to be desired. One interesting approach is to look at agents able to support the DM to express and model their preferences. Agents adhering to a belief-desire-intention (BDI) architecture.a software model that can accommodate for qualitative knowledge, are a promising kind of agent that can address this issue.

The agents should be able to model a DM's preferences in such a way that they could be used to find solutions that satisfy the DM. The agents can be implemented as standalone entities or be made part of some existing interactive methods by enhancing them. The implemented agents will be made part of the DESDEO framework.This topic has a lot of potential for novel contributions in the multiobjective optimization field of research. This topic is ideal for someone who is interested in pursuing doctoral studies after graduating or is simply interested in a challenging MSc thesis topic.

Required skills

Prior experience in multiobjective optimization is desired. You should also be proficient in Python and Linux environments. Prior experience in agent systems is also beneficial, but not required.

Learning outcomes

You will get first-person experience working in a research group. Your knowledge in interactive multiobjective optimization will increase significantly, and you will have made significant contributions to open source software. This is a good opportunity to boost your GitHub profile, if desired.

Moreover, you will be ready to pursue doctoral studies after your thesis. You may also expect your master's thesis to be eligible to be extended into a conference or journal article.

Examples of tasks in this topic

- Familiarizing yourself with the BDI architecture and its applications in the literature.
- Exploring possible ways for BDI agents to learn and model a DM's preferences.
- Implement a BDI agent that can learn and model preferences and validating your method either numerically or with a real DM, or both.

Topic 6: Agent-based negotiation support for group decision making in multiobjective optimization (Bekir Afsar and Kaisa Miettinen)

Existing interactive methods typically involve a single decision maker, which is not the case in various decision making situations. In many real-world applications, there exists more than one decision maker (stakeholder) in identifying the best compromise solution that should satisfy all parties involved. In such solution processes, collaborative preference elicitation and negotiation processes are necessary to build group consensus.

Negotiation protocols are a well-studied and established research field in multi-agent systems that enable groups of agents to reach a mutual agreement in dynamic environments to carry out the tasks assigned to them. Because the agents are autonomous and can be reactive or proactive, negotiation is essential for managing such multiple intelligent agents. The negotiation process can take numerous forms, such as auctions, contract net protocols, or argumentation.

During the interactive solution process, each decision maker provides their preference information (e.g., a reference point), which may be contradictory due to their diverse roles. In this thesis, you will explore ways of applying multi-agents and negotiation support to aggregate these possibly competing preferences and create a compromise preference information satisfying all parties involved. Indeed, we support a group of decision makers in finding compromise preferences with the use of preference agents representing individual decision makers. In addition, existing agent-based negotiation support protocols will be applied to enable preference agents to reach an acceptable group preference (e.g., compromise reference point), which is then incorporated in the interactive solution process.

Required skills

Prior experience in multiobjective optimization and multi-agent systems is required. You should also be proficient in Python and Linux environments.

Learning outcomes

You will get first-person experience working in a research group. Your knowledge in multiobjective optimization and multi-agent systems will increase significantly. Moreover, you will be ready to pursue doctoral studies after this thesis. Lastly, you may also expect your master's thesis to be eligible to be extended into a conference or journal article, if you like.

Examples of tasks in this topic

- Performing a literature review of existing agent-based negotiation support protocols.
- Constructing preference agents which model the decision maker's preferences.
- Applying one of the existing negotiation protocols suitable for group decision making context on multiple preference agents to reach group consensus.

Topic 7: Explainable artificial intelligence/machine learning in modeling data-driven multiobjective optimization problems (Bekir Afsar, Pouya Aghaei pour and Giovanni Misitano)

In data-driven multiobjective optimization the problems considered are often based on some real-world data. Before any optimization process, the multiobjective optimization problem must be modeled. In other words, the objectives, constraints, and decision variables must be defined. Domain knowledge of the problem is therefore necessary, which is why the presence of the DM or some other domain expert is crucial during the modeling process.

Machine learning (surrogates) is often used in modeling the multiobjective optimization process due to the complexity of the data. Typically, the machine learning models used are black-box in nature, i.e., it is not clear to an outside observer how the model makes predictions. This can be a problem, for example, in the case of objectives in a multiobjective optimization problem are modeled with black-boxes in a high-stakes domain, such as healthcare. The predictions made by the machine learning model must be justifiable and explainable.

Explainable artificial intelligence (XAI) is a research field that studies the prospect of explaining the predictions made by black-box machine learning models among other things. While machine learning has been utilized in multiobjective optimization before, the inclusion of XAI is still a novel concept. XAI could help make the predictions in data-driven multiobjective optimization less oblique, justifiable, and explainable.

In this thesis, you will explore the novel prospect of utilising XAI methods in data-driven multiobjective optimization. For example, your thesis could consist of a real-life case study where a data-driven multiobjective optimization problem is modeled using XAI. Being novel, this topic can lead to a scientific publication.

Required skills

Prior experience in multiobjective optimization is desired. You should also be proficient in Python and Linux environments. Prior experience in agent systems is also beneficial, but not required.

Learning outcomes

You will get first-person experience working in a research group. Your knowledge in multiobjective optimization will increase significantly. Moreover, you will be ready to pursue doctoral studies after this thesis. Lastly, you may also expect your master's thesis to be eligible to be extended into a conference or journal article, if you like.

- Examples of tasks in this topic Performing a literature review of existing XAI methods to grasp the idea of explaining machine learning models.
- Explaining a data-driven multiobjective optimization surrogate model by utilizing existing XAI methods.
- Studying the benefits of having explanations on the optimization model.

III- Software development for decision making (DESDEO)

Topic 8: Design an interface for interactive methods (Johanna Silvennoinen, Giovanni Misitano and Bhupinder Singh Saini)

Multiobjective optimization considers problems with multiple conflicting objectives. Finding a best solution to these problems needs the involvement of a domain expert, known as a decision maker (DM), whose knowledge and preferences can be used to find preferred solution(s). An optimization process in multiobjective optimization typically consists of exploring a particular set of (compromise) solutions known as Pareto optimal solutions.

Based on how preferences are incorporated in the solution process, multiobjective optimization methods can be divided into three distinct categories: a priori, a posteriori, and interactive methods. As the name suggests, preferences are incorporated in the solution process before and after an optimization process has taken place in the first two kind of methods, respectively. But in interactive methods preferences, and correspondingly the DM, are incorporated during the optimization process. This has many advantages. For instance, interactive methods can focus on a particular subset of the Pareto optimal solutions that is interesting to the DM based on their preferences.

This can not only save computational costs, but it also allows the DM to focus on solutions that best meet their current preferences. Designing interfaces for interactive multiobjective optimization methods is a challenge. The data being visualized is often multidimensional (more than three dimensions) and the interface must support the DM in expressing their preferences in different ways. Moreover, different DMs may prefer the same data to be visualized in different ways, or they may prefer to express their preferences in varying ways as well. These needs make the design and implementation of interfaces for interactive methods challenging.

Required skills

Prior experience in multiobjective optimization is useful, but not required. You should be proficient in Python, TypeScript and Linux environments. Particularly, you should have at least some prior experiences in developing React apps. Knowledge of D3.js is also an advantage. The focus in this thesis is on the practical side.

Learning outcomes

You will get first-person experience working in a research group. Your knowledge in interactive multiobjective optimization will increase significantly. You will be making contributions to open source software, which can boost your GitHub profile to the next level. You will also gain considerable experience in web development.

Examples of tasks in this topic

- Working with the various components found in the DESDEO framework.
- Extending the existing web-based interface with a dynamic layout for some existing interactive method.
- Doing full-stack web development with a particular focus on the front-end.

Topic 9: Physical interfaces for interactive multiobjective optimization (Atanu Mazumdar, Johanna Silvennoinen, Giovanni Misitano and Bhupinder Singh Saini)

In this thesis, you will work on the development of fully modular physical user interfaces for interactive multiobjective optimization algorithms. This work will be done as an extension to the DESDEO framework (desdeo.it.jyu.fi), which implements interactive algorithms and supports the use of physical interfaces (such as buttons and sliders) built using microcontrollers such as Arduinos.

Additionally, you can integrate haptic feedback and braille script modules. Your work will include creating new ways of physically interfacing with interactive algorithms, creating custom hardware to try out and test these new interfaces, and implementing software connecting the hardware to the algorithms. This is a novel field where you are expected to mix engineering and design mindsets.

Your work may also include examinations of how humans represent tactual information and how this kind of knowledge can be incorporated into tactual design of components within physical user interfaces. Further investigation can be conducted with brain interface devices to understand the effect of using physical interfaces. You will be able to write a publication based on your work, if you wish.

Required skills

Knowledge of multiobjective optimization is useful but not required. You should be comfortable with Python and JavaScript/TypeScript programming (for working with the DESDEO framework). Experience in working with Arduinos (ATmega series, STM32, ESP32 etc.) and other electronic components, and hence C/C++ programming is also required. Prototyping circuits on breadboards, basic soldering skills and PCB designing will be helpful.

Learning outcomes

You will get experience in working with a research group on an open-source project under active development. You will learn about the current state-of-the-art in interactive multiobjective optimization. You will gain experience in creating custom hardware using microelectronics and learn about how to create good user interface designs.

Examples of tasks in this topic

- Building novel physical interfaces to interact with various multiobjective optimization methods developed in our group.
- Exploring previously uncharted research areas in our field, such as how humans represent tactual information.
- Possibility to even develop tools to support visually impaired people to operate our methods.

Topic 10: Interactive visualizations for multi-criteria decision support under uncertainty (Babooshka Shavazipour)

Besides multiple conflicting objectives, real-life problems are characterized by uncertainty. It is desirable to make robust decisions that are not too sensitive to the consequences of uncertainty, i.e., they perform well in a wide range of future states or events (scenarios).

In scenario-based multiobjective optimization problems, the performance of a decision should be evaluated regarding each objective in different scenarios, bringing an additional dimension to the performance evaluation and complicating the DM's task. Visualization supports are needed to help the DM understand and compare trade-offs between different objective functions and evaluate and analyze trade-offs between the performances of a solution in various scenarios (called trade-offs between scenarios). Recently, two visualization methods: a novel extension of empirical attainment functions for scenarios and an adapted version of heatmaps, have been proposed [2] to help decision-makers gain insight into realizations of trade-offs and comparisons between objective functions in different scenarios.

In this thesis, you will implement an interactive version of these visualizations in the DESDEO-components library and connect them to the DESDEO user interface. Note that the static version of the codes is available in the R programming language. Your thesis can also consist of designing an experimental study (e.g., with some students) to test the utility of these visualizations compared to some others. In this case, you may contribute to the literature that can lead to a scientific publication.

Required skills

You should be proficient in Python. Prior background in mathematics/statistics and R is also beneficial.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support in general and in scenario-based multiobjective optimization will increase significantly, and you can make significant contributions to open source software development.

Examples of tasks in this topic

- A literature review of interactive visualizations.
- Implementing (coding) interactive visualizations in the DESDEO framework and testing them by reproducing the figures of the paper.
- Performing an experimental study with human participants.

[2] Shavazipour B, López-Ibáñez M, Miettinen K. Visualizations for decision support in scenario-based multiobjective optimization. Information Sciences [Internet]. 2021;578:1–21. Available from: https://doi.org/10.1016/j.ins.2021.07.025

Topic 11: Showcasing the modularity of DESDEO (Kaisa Miettinen and Giovanni Misitano)

By choosing this topic, you will be embarking on a journey during which you will learn about different interactive multiobjective optimization methods. You will delve into the practicalities of each method and will get a hands-on experience on solving multiobjective optimization problems based on real-life cases. You will also experience collaboration on an open-source project, which is a seldom taught but ever needed skill; both in industry and in the academic world.

In this thesis, we expect that you will combine pieces of existing multiobjective optimization methods creating new composite methods using DESDEO. These new methods should be tested on real-life problems and mutually compared. We expect a sound scientific analysis in the comparison of the methods. We also expect you to contribute to the DESDEO framework during your thesis work.

These contributions should be related to combining existing methods, for example, contributions easing the combination process are more than welcome. To our knowledge, this kind of "mix and matching" of interactive multiobjective optimization methods has not been studied much in the current literature. Therefore, you can also expect to be able to write a publication based on your master's thesis.

Required skills

Prior experience in multiobjective optimization is desired. You should also be proficient in Python and Linux environments.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support and interactive multiobjective optimization will increase significantly. You may also expect your master's thesis to be eligible to be extended into a conference or journal article.

Examples of tasks in this topic

- Combining pieces of existing methods for interactive multiobjective optimization into new methods.
- Testing your newly implemented methods with problems based on real-life cases. You have also the possibility to test your methods with human decision makers.
- Implementing the new methods as part of the DESDEO framework as open source software.

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IV- Cognition and decision making

Here are some of the possible topics. These can have different research approaches, for example empirical studies with decision makers, more theoretically oriented reviews focusing for example on method development or implementing visualization elements to interactive methods.

Supporting decision making with visualizations

1. Fitting to the cognitive styles of the Decision Maker. What visualizations best support decision makers in different decision contexts?
2. Going to the element level. How the information is presented to the decision maker. How visualizations can be enhanced by examining the constructing elements in detail.
3. How different visualization methods affect the decision process. Looking into more visualization methods in the literature and examine how final solutions are affected by the utitized visualizations

Cognitive and affective de-biasing in multiobjective decision making with interactive methods

1. Examining different heuristics and biases essential in multiobjective decision making with interactive methods from expert decision making perspective. What are the central ones and which phase of the decision process these occur (positive and negative aspects).

2. What de-biasing methods are suitable for this decision making context. What other methods could be utilized and developed? Can most suitable de-biasing methods be implemented to the interactive methods?

Topic 12: Cognitive biases in interactive multiobjective optimization (Johanna Silvennoinen)

Decision making with multiple conflicting objectives is a complex cognitive-affective process. Interactive multiobjective optimization methods are in a central role in aiding decision makers to solve complex problems. Research is required to understand what kind of cognitive biases occur and affect decision making processes and how interactive multiobjective optimization methods could be designed to inform decision makers of cognitive biases enabling making better decisions.

Overall, cognitive and affective processes in decision making with interactive methods in multiobjective optimization is a vast research area with many research topics. This includes, for example, examinations of what cognitive and affective biases are central within this decision making context and how to implement information of these in a manner that aids the decision makers. Multiobjective optimization with interactive methods is a unique research context for human-computer interaction, therefore other biases besides the most frequently mentioned in the judgment and decision making literature (e.g., anchoring and availability), can have an important role. Thus, research is required to understand context-specific biases for enabling better decisions.

In addition, efficient cognitive and affective de-biasing methods are important to be studied. These can include approaches, such as the role of metacognitive processes and possibilities of group decision making procedures towards debiased decision making, to name a few. Also, expert thinking in decision making as its own sub-discipline is essential to be examined within this interaction context. All of the issues raised above can also be examined from expert thinking perspective.

All the research topics introduced above have a lot of potential for novel contributions in the multiobjective optimization field and within decision making research. These research topics are ideal for someone who is interested in pursuing doctoral studies after graduating but can also be conducted within a master's thesis (with a more narrowly scoped research topic).

Required skills

Prior knowledge of multiobjective optimization and cognitive science, especially regarding decision making is desired, but not mandatory for master's thesis. For doctoral studies, a master's degree from applicable research areas is required.

Learning outcomes

You will get experience in working in an interdisciplinary research group, combining multiobjective optimization and cognitive science. This kind of knowledge and expertise is essential for current and future human-centered technology development. If the master's thesis is completed within one of these research topics, this gives you excellent capabilities of pursuing doctoral studies. There is also a possibility to extend your master's thesis into a conference or journal article with moderately little effort, if you prosper in your thesis.

Examples of tasks in this topic

- A literature review of cognitive and affective biases central in multiobjective decision making or a literature review of cognitive and affective de-biasing methods in multiobjective decision making.
- Implementation of methods and design of experimental studies (e.g., implementing de-biasing methods and conducting experimental studies on how these can aid the decision makers towards better decisions.
- Performing the designed experimental studies.

Topic 13: Supporting decision making with visualizations (Kaisa Miettinen, Johanna Silvennoinen, Giovanni Misitano and Bhupinder Singh Saini)

Interactive multiobjective optimization methods are based on interactive visualizations as the concrete contact points between the decision support system and the human decision maker. Thus, in the core of this research area are interactive information visualizations. Visual information can be presented in numerous different ways. In-depth knowledge can be obtained in studying different visual elements of visualizations and the ways these are understood and how these can be designed in a way that supports decision makers. For example, knowledge of human visual information processing can be implemented as design solutions giving more predictability to the way decision makers cognise visualizations. For interactive visualizations to aid decision makers, it is highly important to examine how information is needed to be presented. This topic includes, at least, the following research topics: reviewing possible visualizations to be implemented, examinations of how different visualizations affect decision making processes and solutions, experiments on how different visualizations are cognised with different interactive multiobjective methods, how to enhance interactivity of visualizations and, how to incorporate decision maker's cognitive styles with different visualizations. Research is required to understand what kind of visualizations are efficient in this human-computer interaction context from varying perspectives.

In addition to the topics introduced above, much research is needed in developing research methods on how to study decision maker's understandings and experiences of utilizing interactive multiobjective optimization methods. These includes, for example, developing validated measurements within this research contexts for cognitive load, usability, understandability of visualizations, and for example, user satisfaction. These research topics have a lot of potential for novel contributions in the multiobjective optimization and information visualization fields. The presented research topics are ideal for someone who is interested in pursuing doctoral studies after graduating but can also be conducted within a master's thesis (with a more narrowly scoped topic). These topics can also be conducted as pair-wise master's theses, combining expertise from students of cognitive science and mathematical information technology.

Required skills

Prior knowledge of multiobjective optimization and cognitive science, especially regarding decision making, information visualization, and method development in human sciences are desired, but not mandatory for a master's thesis. For doctoral studies, a master's degree from applicable research areas is required.

Learning outcomes

You will get first-person experience working in or with an interdiscplinary research group combining multiobjective optimization and information visualization design from the perspective of cognitive science. This kind of knowledge and expertise is essential for current and future human-centered technology development. If a master's thesis is completed within one of these research topics, this gives excellent capabilities for pursuing doctoral studies. There is also a possibility to extend the master's thesis into a conference or journal article with moderately little effort, if you prosper in your thesis.

Examples of tasks in this topic

- Performing a literature review on how visualizations have been used in the context of multiobjective optimization to support decision makers.
- Exploring the literature on how different visualizations have been perceived by humand in different contexts.
- Designing an experiment to measure how visualizations need to be presented to best support human decision making in the context of multiobjective optimization.
- Conducting the designed experiment(s). The experiments can also be conducted as part of some continuation work based on your MSc thesis, such as a journal or conference article.

V- Real-life applications

Topic 14: Personalized medicine (Babooshka Shavazipour, Bekir Afsar)

When a clinician selects an exercise therapy for a patient, (s)he must simultaneously consider several perspectives like reducing pain, improving physical function, reducing the number of supervised sessions, increasing adherence, keeping the cost reasonable, etc. Some of them are conflicting since improving physical function may need extra supervised sessions and increase cost, and the task is to find the best balance, i.e., the best compromise. However, there are no explicit guidelines or tools available to support clinicians. Therefore, decision support tools are needed to compare several compromises with different trade-offs and confidently choose the best-fitted exercise therapy considering the characteristics of individual patients.

Recently, in the Multiobjective Optimization Group, we have started developing data-driven interactive multiobjective optimization methodology [3], which is different from the conventional meta-analyses carried out in the clinical field of research, to find a straightforward way to choose a personalized best-fitted exercise therapy for each patient based on the available research data.

As a part of it, we need prediction models for our data-driven consideration to estimate the efficiency measurements of the selected trials based on several identified objectives. Unfortunately, most of the available trials include only a few tens of participants/samples, while state-of-the-art predictors (e.g., (deep) neural network and Gaussian regression) often need several hundred/thousand samples to provide predictions with reasonable accuracy. So, they cannot be simply applied in exercise therapy studies.

In this thesis, you will explore the existing literature on handling small datasets (with machine learning/statistical methods or both) and identify potential ways/methods to be used as prediction

models in dealing with small datasets. Your thesis can also consist of testing various prediction models in a real case study (e.g., a published randomized control trial) to compare their performances. In this case, you may contribute to the literature that can lead to a scientific publication.

Required skills

Prior knowledge of artificial intelligence, statistics, and multiobjective optimization is desired. You should also be proficient in programming with Python/R or both.

Learning outcomes

You will get first-person experience working in or with a research group. Your knowledge in decision support in general and in data-driven interactive multiobjective optimization and sport-based applications will increase significantly. Moreover, you will be ready to pursue doctoral studies after your thesis if you like.

Examples of tasks in this topic

- Performing a literature review on handling small datasets with machine learning or statistical methods.
- Identifying and testing potential methods on a real-case dataset.

[3] Shavazipour, B., Afsar, B., Multanen, J., Miettinen, K., & Kujala, U. M. (2022). Interactive multiobjective optimization for finding the most preferred exercise therapy modality in knee osteoarthritis. *Annals of Medicine*, *54*(1), 181-194.