AN OVERVIEW ON MULTI-OBJECTIVE OPTIMIZATION AND DECISION MAKING

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In the field of operations research and optimization engineering using computer science, the core topic always was and still about finding optimal, acceptable and feasible solutions in complex spaces, and we mean by 'complex spaces' here spaces that are large and highly constrained and intricate: The real world is a perfect materialization of such space.

From an algorithmic perspective, finding optimal and acceptable solutions for real world problems is challenging. The introduction of the synonymous concepts of Multi-Objective Optimization and Decision Analysis (MODA) or the Multi-Criteria Decision Making (MCDM), which are and modern variants of optimization and decision making, as a key lever that takes into consideration the fact that in order to search for and find the optimum solution for a real world problem, we have to manage and combine between the features of Multi-Criteria Decision Aiding (MCDA) and Multi-Criteria Optimization (MCO), both form the combined science of making "good" decisions through the process of systematically studying and analyzing the different alternatives, options, choices, scenarios…

Optimization and decision making in real world problems often, if it's not always, involve conflicting parameters (criteria). For example, chosing a means and a path to travel from a point to another: it should be safe, fast, quick, cheap, comfortable, convenient, reliable… but you can't have it all! Or you are invited to engineer an industrial process that should be cost efficient, scalable, reusable, eco-friendly…

Finding THE optimum solution, usually referred as the 'ideal', where all objectives are at their optimal level, is the exception and not the rule. So the main idea is to reach a compromise, a win-win situation.

As a part of the scientific field of operations research and optimization engineering using computer science, we can define the Multi-Objective Optimization and Decision Analysis (MODA), or it synonym Multi-Criteria Decision Making (MCDM), as a multi-disciplinary field based on other scientific disciplines: Multi Criteria Decision Aiding (MCDA) and Multi-Criteria Optimization (MCO).

So the Multi-Objective Optimization and Decision Analysis (MODA), or the Multi-Criteria Decision Making (MCDM), deals with Multi-Criteria Decision Aiding (MCDA) and Multi-Criteria Optimization (MCO), or combinations of these.

We can define:

Multi-Criteria Decision Aiding (MCDA), also called Multi-Criteria Decision Analysis, as a scientific field that studies the evaluation of a finite number of alternatives based on multiple quantitative criteria. It supplies tools and methods to compare, evaluate and rank solutions.

Multi-Criteria Optimization (MCO), also called Multi-Criteria Design or Multi-Criteria Mathematical Programming, a scientific field that studies the search, in a usually large space, for optimal solutions while taking into consideration a

number (multiple) of criteria and constraints. The size of the search space makes the inspection of all the solutions usually impossible.

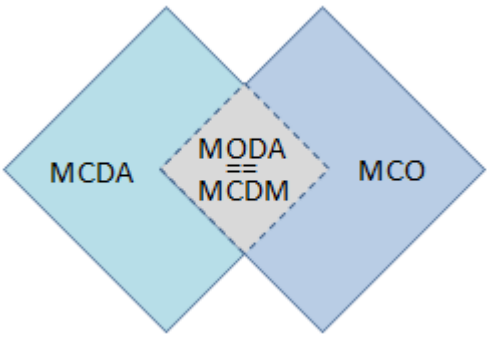

Figure – MODA/MCDM field situation

Due to the highly complex, constrained and intricate properties of its application field, the multi-objective optimization and decision-making problems present a rich algorithmic and mathematical structure, especially algorithms that use parallel computing in order to solve complicated application problems. In addition, their high relevance in various application fields in real life has recently led to an important rise in the interest aroused not only by the scientific community but also by different types of profiles: investors, influence groups and decision-makers (lobbyists, political parties, NGOs…) thus resulting in a very significant increase in research activities and the investment flows that comes with it.

In our work, we will therefore try to cover the subject from a broad perspective and understand its fundamentals from an algorithmic point of view to enlighten the reader and arouse his curiosity, thus prompting him to think further:

We will theoretically exhibit the foundations of Multi-Objective Optimization and their solutions methods as well as the tools for their performance-assessment. Also, we will provide an overview on formal processes and decision aid tools for conflicts resolutions.

Then we will present case studies from the literature, particularly the ones in real life application domains of decision making.

The main goal here is to introduce the reader to this fascinating field of interdisciplinary sciences and its foundations by providing a starting point through the exposition of its fundamentals and the different methods, techniques, applications as well as the terminology necessary to guide him in his quest for knowledge. References will of course be given to the reader in order to help him deepen his research and help point into more specialized topics.

Number of reasons makes the Multi-Criteria Optimization and Decision Making a thrilling and exciting scientific field of computer science and operations research, the most important one is the fact that different scientific fields are addressed in MCO and MCDA, so in MCDM.

Firstly, in order to build and develop the 1st fundamental layer methods for the MCO, we have to deal with elementary structural sciences, such as relational logic, algorithmic, operations research and numerical analysis. Eventually, some of the questions that we have to ask are:

How can we formalize a decision/optimization, problem in the right way?

What are the key differences between single-objective and multi-objective optimization?

How can we order the possible solutions? And what are the different types of rankings and orderings that are used in decision theory? And how are they related to each other?

What are the formal conditions that needs to be satisfied for a solution, or a number of solutions, to be optimal for an already given decision model or optimization problem?

How can we efficiently build optimal solutions providing algorithms, or at least ones that obtain approximations to them?

What is, from a geometrical stand of view, the right structure of solutions for problems with numerous optimal solutions? ...

Then when it comes to MCDA, and particularly making decisions in real world with all its constraints and parameters, these decisions will be made by humans, or machines that emulate human behavior, intelligence and even emotions, which are responsible for all the resulting impacts and consequences. In order to understand how the decisions are made, psychology of individuals and organizations needs to be studied. Some of the questions that might arise are:

What are our aims, goals and objectives? What makes it difficult to properly state them? How do we identify them? Can a formal process of doing so be supported?

Which strategies are used by people, humans and machines, when it comes to making a decision? And do they even use strategies? How satisfaction can be measured and what are the promising strategies to obtain such result?

What are the cognitive and behavioral aspects in decision making? How can decision making support systems be built in a proper way that take into consideration the cognitive and behavioral capabilities and limits of humans?

How do people, individuals and groups, come to decisions? What are the possible conflicts that can emerge through the decision making process? Can they be avoided and how? How can we deal with minority interests in a fair and democratic decision process? Is it possible to integrate all these aspects into formal decision processes and models?

Concretely, decisions are related to real world problems and are variable given the application field, so we may answer differently but specifically to these questions:

What is the set of possible alternatives, available options and best choices?

What are the means and the best practices to quantify a criterion or criteria? Experiments? Surveys? Evaluations? Are there any specific problems with these measurements given the field of application? What are the risks, dangers and costs? And how can we deal with them or even tackle them? Is there any possible uncertainties? (Off course yes!)

Given a field, or numerous fields, of application, what are the 'use-proof' decision processes? And what effects and implications have these best-practices on the engineering of decision support systems for the specific field or fields?

Are there specific optimization and decision support processes for specific existing problems? If so, what are the levels of acceptance and performances of these in practice?

What can we do about the reality of uncertain and distortion in today's world…

By this (tiny) list of questions, we are trying to have a panoramic perspective of the field, like some kind of bird's eye view, but the most important is that we are trying to arouse the reader's curiosity when it comes to the richness of the subject.

Practically, we will concentrate on the structural side of the Multi-Objective Optimization and Decision Making. However, we will also discuss the human-centric side of decision making, and in the other hand we will try to approach the problematic of Multi-Objective Optimization's utility and usability in application problems.

As a recap for the overview, it is important to note that the research field is very active and progresses have been recently made in every aspect of it. And in practice, it is wise and even mandatory to consider the human aspect of decision making, which can often be irrational or based on subjective criteria, but at the same time considers far more important things such as morality, ethics and deontology, which are key "criteria" that machines can't "understand" and emulate properly still to today.