Multi-criteria Decision-making

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1 Project Goals

Decision-making occurs to each one of us on a daily basis, yet rarely do we consider the cognitive processes that occur when making choices involving different alternatives and characteristics. What causes one alternative to appear more appealing to an individual (or a group of) decision-maker(s)? How do we choose according to a set of criteria when certain there exists conflict between some of them?

When choosing among a set of options, a decision-maker often uses a set of measuring criteria to rate the desirability of available alternatives. Adapting such a multi-criteria decision-making problem to the standard optimization model, we get that each alternative is formulated as an objective function, while each criteria is represented as a constraint. The i^{th} coefficient or weight of a constraint correspond to the importance of the i^{th} criterion (here we assume that weights are identical across all objectives). In this model, it is evident that the optimal alternative becomes the constraint with the highest weighted sum.

This model assumes that we have ratings for each one of these criterion and alternative-criterion intersections. However, human ratings of a criteria and how well an alternative satisfies it are generally imprecise due to cognitive loads associated with scoring each alternative, regardless of it is on a discrete or continuous scale. Consider the situation when the user is required to make a rating about the importance of each criteria and how well every alternative satisfies it - this process is cognitively demanding and especially tedious when each criterion's score is uniquely defined for every available alternative.

Unfortunately, in decision-making problems with multiple criteria, some of them may be in conflict with one another. That is, if satisfying one criteria necessarily causes another to become unsatisfied or less satisfied, and both criteria of concern have positive weights (importance), then the optimal solution would need to sacrifice some of one criteria for the other.

This projects aims to explore resolutions to these multicriteria decision problems where conflicts may arise. It will also explore methods of reducing the need human ratings so that weights of certain criteria can be predicted or suggested rather than elicited from the decision-maker. Ultimately, the objective of this project is to design, implement, and test an interface that visually represents a decision problem in a semi-automated fashion using techniques of weight prediction and calculated objectives to sort the various available choices.

2 Methodology & Relevant Research

Several direct elicitation techniques exist such as point allocation (where user distributes a finite amount of points among available options) and direct rating methods (where there exist no upper limit to the total distribution of points) [1]. As previously discussed, this method is costly for the user and unattainable when a large number of attributes or choices are involved. Requiring slightly less effort are the ranking methods, including the rank-sum weights, where each item's ordinal number reflects their respective weight or rank reciprocal weights where numbers are assigned according to the inverse of the rank order, or a linear combination of the RS and RR weights. Geometric weights is similar to rank sum weights except for a multiplicative factor. All of the abovementioned methods were analyzed and validated by Danielson and Ekenberg [2].

In the case when there are multiple efficient solutions to the same problem, methods of helping decision-makers in their selection of a final solution among a set of equally optimal solutions are known as the multicriteria decision aid (MCDA) [3]. In [4], Papathanasiou and Ploskas explore the practical and theoretical aspects, including methods such as TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution), PROMETHEE (Preference ranking organization method for enrichment evaluation), goal programming, as well as algorithms involving fuzzy number theory and group decision making. However, with possibly conflicting criteria these approaches could lead to sub-optimal alternative choices, they can however be avoided with approaches in machine learning.

Finally, there are methods used in marketing models such as the multinomial, multiattribute logit approach [1]. In these models, each alternative is defined as a function of the utility that the alternative / option itself holds for the decision-maker. This utility is simply a weighted sum of the criteria scores. In [1], these utility weights are calculated using the maximum likelihood technique, whose estimations are known to be consistent and asymptotically consistent. However, this approach and similar methods of linear regression would require information from users' utility measurements of each alternative. This would be difficult to acquire at a large scale from the decision-maker when they are still exploratively gathering information about their decisions, so for instance the criteria (attributes in this model) may be variable or unknown.

Since these techniques all have potential for decreasing the cognitive costs of making a decision, it is unrealistic to reach full comprehension and evaluation of each one. This project will begin by comparing and choosing one or more of the most effective and efficient solution, followed by a validation of the technique through implementation and user testing.

3 Bibliography

- Gensch, D., & Recker, W. (1979). The Multinomial, Multiattribute Logit Choice Model. Journal of Marketing Research, 16(1), 124-132. doi:10.2307/3150883

- Danielson M., Ekenberg L. (2014) Rank Ordering Methods for Multi-criteria Decisions. In: Zarat P., Kersten G.E., Hernndez J.E. (eds) Group Decision and Negotiation. A Process-Oriented View. GDN 2014. Lecture Notes in Business Information Processing, vol 180. Springer, Cham

- Ehrgott, M. (2005). Multicriteria Optimization. Springer-Verlag, Berlin, Heidelberg.

- Papathanasiou J., Ploskas N, (2018) Multiple Criteria Decision Aid Methods, Examples and Python Implementations, vol 136, Springer

4 Timeline

a. Fall semester: complete literature review for ways of reducing required ratings and solving for multi-criteria decision making problems.

b. Spring semester: validate implement and/or optimize a method of solving multi-criteria decison problems.

5 Fall 2019 - Spring 2020 Schedules

Fall	Spring
CSCI 275 Abstractions	PYSC 207 Memory
NSCI 201 Intro to Neuroscience	NSCI 360 Cognitive Neuroscience
MATH 332 Nonlinear Optimization	STAT 339 Probabilistic Modeling and Machine Learning
CSCI 401 Honors	CSCI 401 Honors