Thesis proposal

Supervising team (Sorbonne) : DESTERCKE Sébastien (Heudiasyc), Patrice Perny (LIP6) and Olivier Spanjaard (LIP6)

***Title** : Managing imprecision and inconsistency in robust combinatorial optimisation*

Summary
The goal of the project is to use rich uncertainty modelling tools to model uncertainty and manage inconsistencies that can arise in robust combinatorial optimisation problems, be it in the preferences provided by the decision maker (e.g., to obtain an objective function) or in the description of the optimisation instances (uncertain variables or costs). Uncertainty will typically come from the lack of initial knowledge, while inconsistency will be generated either by inconsistent answers from the decision maker (user errors), or by ill-chosen modelling hypothesis (model choice errror) by the analyst.

Topic description

1) Scientific context

There are lots of decision problems in artificial intelligence where the solution space is of combinatorial nature: computational social choice (allocating goods in a fair way, …), planification (autonomous transports, virtual agents, …), product configurations (Touristic travels, cars, …). Two main sources of uncertainty can arise in such kinds of problems: on the one hand the uncertainty about the preferences of the decision maker/user regarding the different solutions, on the other hand uncertainties linked to the constraints limiting the space of possible solutions.

Two classical means to model this uncertainty et make inference despite of it are robust approaches on the one hand (typically through minimax or regret minimax) [1], and probabilistic approaches on the other hand [2]. While the robust approaches provide strong guarantees (particularly useful in critical applications) at the price of strong hypothesis (valid model hypothesis and error-free user replies), the probabilistic ones only provide guarantees in expectations (whose interest for non-repeated or non-statistical problems can be questioned), but allow one to integrate uncertainties in the user replies (for example in Bayesian approaches) or in the model choice (for instance through likelihoods).

The use of other uncertainty models, that can complement and generalize probabilities, allow one to keep the strong guarantees of robust approaches while being free of their constraining hypothesis. For instance, using a possibilistic model allow one to obtain better results in presence of uncertainty in the user response, while detecting potential inconsistencies [3]. If the use of such models is very promising in terms of properties, it also opens up many questions and face new challenges:

- For the moment, their use mainly concerns decision maker preferences over non-combinatorial spaces of alternatives that can be enumerated explicitly. One challenge therefore concerns their extension to combinatorial problems where uncertainty can also concerns the instance constraints [4] (e.g., uncertainties connected to meteorological conditions for path finding problems in communication or transport networks, uncertainties over costs).

- Also, while such approaches are well-tailored to identify inconsistencies arising from potential errors, there is to this day very little research done to identify the sources of those inconsistencies and to propose adequate reparation to cancel or reduce this inconsistency. On this last point, one could think of using tools issued from logic, and notably possibilistic logic [5]. One should note that this absence of methods to deal with inconsistencies concerns both the non-combinatorial and combinatorial cases. As inconsistencies result from the collection of information and from the associated estimation or learning process, these two first tasks first need to be dealt with to solve the inconsistency problem. However, results concerning these steps already exist, and could be used in this work.

The proposed PhD topic aims at solve, at least partially, those two mentioned issues. Solving the first issue is essential to apply uncertainty-aware approaches to large scale problems, while the second issue corresponds to important scientific challenges (model choice, error repair), to which above-mentioned approaches can bring new and relevant answers.

Concerned fields and skills

As mentioned, the two main fields directly concerned by this topic are **decision theory and algorithmic** and **uncertainty reasoning.** These two sub-fields of artificial intelligence are also key concerns in other scientific fields, such as operations research and robust optimisation.

2) Targeted goals

During the thesis, we expect to advance towards the following goals

Long-term :

- **Robust decision under imperfect information.**
  The works intended in this thesis aim at establishing general solution strategies to take decision in imperfect situations. One goal is to exploit the potential advantages of uncertainty models departing from standard probabilities, these models having already proved useful in simpler problems.
- **Model and observation selection**
  Choosing the right models as well as the right observations in case of inconsistency is a difficult problem, often solved through probabilistic, averaging means or with dedicated scores. Our initial ideas which consists as seeing this problem as an information fusion problem where one searches to reduce observed inconsistency seems both original and well-suited to non-statistical decision problems.

Short term :

- **Robust inferences with complex uncertainty:** a first possible work to undertake is to extend various results to the combinatorial case where uncertainty description is richer (for instance, determining possibly optimal solutions when uncertainties exist over costs and constraints).
- **Managing incosnsistency in multi-criteria decision problems :** a second possible work is to define strategies to reduce or remove inconsistency when observations concerns the decision maker preferences.

5) Thesis environment

The PhD candidate will divide their time between Sorbonne Université (LIP6) and UTC, a member of the Sorbonne Alliance (Heudiasyc). The PhD candidate will benefit from a vibrant scientific atmosphere, as well as a location at the heart of France. The PhD candidate will also be part of the SAFE AI chair, held by S. Destercke, thus providing the candidate with all the necessary funds to have a comfortable environment.

- In LIP6/Heudiasyc : Khaled Belahcene (HDS), Nawal Benabbou (LIP6)
- National & International, notably among the following CNRS working groups CNRS : GdR *IA*, GdRI *AlgoDec*, GdR *Policy Analytics*, as well as with the European *MCDA working group*. Other possible interactions include
    - Paris Saclay : Vincent Mousseau, Wassila Ouerdane
    - IRIT : Romain Guillaume
    - Greyc : Nadjet Bourdache, Bruno Zanuttini

6) Candidate profile and application information

We expect a candidate showing a strong background in either computer science or applied mathematics, with a demonstrable keen interest in either combinatorial optimisation/discrete mathematics or uncertainty modelling. The candidate should also be able to communicate in English and possibly French. Prospective applicants should send the following elements to the supervising team:

- A CV demonstrating that the applicant has the required skill to complete the doctoral program
- A letter of motivation detailing the motivation of the candidate for this particular topic (motivation letters of generic nature will be disregarded)
- A copy of previously obtained grades
- At least two references
- If existing, a way to access their publication records (e.g., google scholar page or similar)
- Any other document the candidate may perceive as relevant

7) References

[1] **Benabbou, N., Gonzales, C., Perny, P., & Viappiani, P**. (2015). Minimax regret approaches for preference elicitation with rank-dependent aggregators. EURO journal on Decision processes, 3(1), 29-64.

[2] Chajewska, U., Koller, D., & Parr, R. (2000, July). Making rational decisions using adaptive utility elicitation. In Aaai/Iaai (pp. 363-369).

[3] **Adam, L., & Destercke, S**. (2021, December). Possibilistic preference elicitation by minimax regret. In Uncertainty in Artificial Intelligence (pp. 718-727). PMLR.

[4] Yaman, H., Karaşan, O. E., & Pınar, M. Ç. (2001). The robust spanning tree problem with interval data. Operations research letters, 29(1), 31-40.

[5] Benferhat, S., Dubois, D., & Prade, H. (1998). Practical handling of exception-tainted rules and independence information in possibilistic logic. Applied intelligence, 9(2), 101-127.