IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

PhD Position :

Contraints Programming and model learning in Stable Matching

1 - Context and funding

The principle of fairness ensures “that equal and just distribution of both benefits and costs and avoid unfair biais”. Recently, computational social choice has become a crucial topic: from now on humans’ preferences must be taken into account in our decisions and optimised solutions. The fair and efficient allocation of resources where different agents having their own preferences is crucial in our highly connected world. Matching is about agents that have preferences and is a significant example for taking an algorithmic approach to a problem coming from economics (see the Nobel prize in Economics for Lloyd Shapley and Alvin Roth), finance and computer science [1,2, 3]. Furthermore, the increase of features, data and choices lead to new combinatorial problems focused on fairness and social impact.
In recent years, new problems have emerged due to numerous concrete applications, such as kidney exchange [4], fair market exchange [5,12], university admission [2] or majority voting [6]. These problems have become application cases in the fields of artificial intelligence (A.I.) and combinatorial analysis.

The objective of this thesis is to focus on the study of families of particular stable matching problems in one or more dimensions [4,14] having mainly quasi-stability notions. This quasi-stability has brought out notions of weak and strong stability, leading to new questions about the construction of matching according to the number of unsatisfied agents and about blocking pairs/triples [10,11].
Agents not satisfied with the proposed arrangements ask for compensations to make the solution more equitable. How to quantify their number and compensations so that they accept the proposed matching? Works on the minimisation of the number of blocking pairs and blocking agents have proposed quite innovative approaches to the measurement of instability [13]. However, the studies are still quite simple and approaches by models learning or symbolic A.I. using complex and efficient Constraint Programming (CP) models would help to obtain an efficiency for the resolution and the proofs. It is on this point that the thesis is positioned.

2 - Research project

Methodology deployed:
1) Learning generic patterns for combinatorial problems with preferences.
The models are more and more oriented towards boolean models often naive but using powerful solvers. There is a real need to optimise the learning of clauses in the defined models. The emergence of Boolean models in non-complete matching problems with the notions of weak and strong stability [10,11,12] encourages the use of SAT solvers of the lazy-clause generation type [13].
Based on the experience of N. Beldiceanu on pattern generation in combinatorial problems [19], we will use the learning aspects allowing to learn from very few data generic patterns for weak or strong quasi-stability problems in bipartite or k-bipartite matching problems with classical or cyclic preferences. These studies do not yet exist in the literature, and would allow to enrich the Boolean models and filtering mechanisms. This would lead to the generation of faster solutions and to the detection of stable, robust, ethical and balanced solutions.

2) Efficient Constraint Programming Models.

Our work in collaboration with UCC (Insight) in Ireland on robust stable marriages [7, 8] and popular matchings [9] has shown the usefulness of Constraint Programming (CP) to propose generic models using graph and permutation structures, as well as preference properties in stable or fair marriages. The same is true for stability and quasi-stability problems that rely on graph, permutation, and algebraic properties [10,3].

Work in Constraint Programming (CP) focuses on some of these notions and properties to optimise the efficiency of existing models [15]. Insight has been working for the last years on quasi-stable 3-dimensional matching problems with cyclic preferences [14]. But these CP models remain relatively classical without trying to develop elaborate filtering rules and adapted search algorithms.

The planned work will therefore focus on theoretical studies in combinatorial optimisation in the service of the defined models and rules for breaking symmetries, filtering and search strategies. But above all, the idea is to use the contribution of graph variables and constraints which are a real serious area for improving CP models for problems based on graph theory, as is the case for stable matchings [18]. The work undertaken in this thesis will allow the development of a new way of modelling these problems with fewer variables and a better use of global constraints linked to graph variables.

The results obtained will be evaluated and published in major conferences/journals, and disseminated on open source platforms. Scientific progress reports and publications will be written every year.

3 -Team supervision and PhD registration

The university partner UCC, and more specifically the Insight research centre, is a major player in AI at the international. It is involved in a large number of European (Horizon Europe), industrial and academic projects.

The two partners have already a long history of collaborations with each other, on topics related to constraint programming and AI. But even more on the subject of stable marriages, indeed from 2013 to 2016 Gilles Simonin, who will supervise this thesis on the IMT Atlantique side, was a senior post-doc at UCC and participated in the supervision of two PhD students at UCC under the direction of Barry O'Sullivan on the subject. His supervision ended when he was already an assistant professor in Nantes at IMT Atlantique.

The strategy of this co-funding is therefore to continue to maintain past collaborations and to consolidate complementary knowledge on stable marriage topics.

One of the strengths of the UCC partner, is first the high level of the researchers involved in the insight center, and also the number of industrial collaborations they have, allowing them to have data and case studies related to the topic presented in this thesis. This is also one of the most common sources of research funding they have, and depending on the projects they obtain, researchers and PhD students adapt their work to these applied cases. Depending on the industrial issues that arise during the 3 years of the thesis, the theoretical and practical input from the thesis will be applied to those that are most appropriate.

The student will divide its time into two periods, one in Ireland and one in France, where frequent working visits and collaborations will take place from one institution to the other.

The PhD student will be registered in two different doctoral schools (one per country).

4 - Candidate profile

The successful candidate will have (or will soon obtain) an MSc (or similar) in Computer Science or related subject.

Experience and strong skills with Constraint Programming and Combinatorial optimisation is required, moreover experience with machine learning is a bonus.

Strong English language skills (reading, writing, & speaking) are expected, but knowledge of French is not required. The working language can be either French or English.

5 - How to apply

Send a letter of motivation, transcript of grades, and your CV to Dr Gilles Simonin (gilles.simonin@imt-atlantique.fr) with the subject beginning with [AI PhD].

6 - References

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