Symmetries in Cost Function Networks OR Solution Distribution in Constraint Search Spaces

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1 Context

Combinatorial problems can be expressed and solved through different paradigms. One of them is Constraint Programming [1], where the basic idea is to allow someone, usually a human being, to model his or her combinatorial problem in the most possible intuitive manner, and to let a program, named solver, finds one or all solutions to this problem.

Unfortunately, making a model in Constraint Programming finally requires a lot of expertise. This is one of the main reasons that prevent Constraint Programming from being widely adopted in the industry, in favor of Operational Research for instance [2]. This research internship is part of a wider and ambitious project aiming to make Constraint Programming easier to use and more common both in academia and the industry.

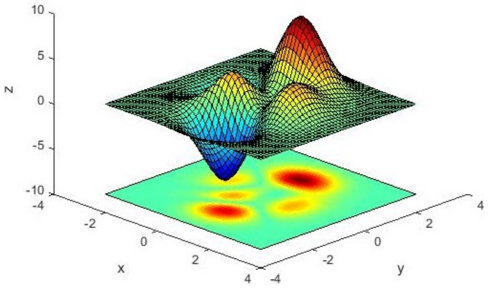
2 Goals and expectations

Cost Function Networks (CFN) [3] is a powerful formalism in Constraint Programming, although not well-known. In addition of a constraint network, it brings an additional structure on *constraint search spaces* a solver can exploit efficiently. However it comes with additional complexity for the user that needs to provide accurate cost functions. One aspect of our research project is to automatically generate cost functions from any constraints provided by the user.

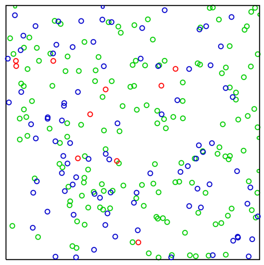
Constraint cost spaces are huge, making hard to generate or learn a good function. For this internship, the student will choose **one** of these two topics. Results in each of these topics would greatly help to automatically define cost functions:

1. Characterizing symmetries like [4] in high-dimensional constraint cost spaces.

2. Estimating where solutions are located in the *constraint search space* [5], detecting if they are structured or not, and characterizing such a structure if it exists.



Topic 1: Symmetries



Topic 2: Solution structures

This internship main objective is then to provide automatic analytical tools to the solver, thus sparing the user to manually define cost functions in his or her model. For both topics, a first step can be to consider specific constraints first, such as `All-Different`, before generalizing to any constraints.

Side goals If the time, abilities and results allow it, the intern student will be able to incorporate this internship's results into existing tools (cf GHOST toolkit [6]). Ideally, theoretical (and possible practical) results would be published in an academic journal or conference.

3 Requirements

A solid background in mathematics and theoretical computer science is required to understand and analyze the functions involved in the study of cost functions Networks.
The student is expected to have sufficient skills in English language to read scientific literature on the topic.

Additional skills in programming (such as C++ in which our current tools are written), in LaTeX(to write articles), and general knowledge on Optimization and/or Constraint Programming solvers are welcome.

4 Contact and other information

The internship will take place at the Nihombashi campus of the RIKEN, in Tokyo, Japan. The intern student will be an employee of RIKEN for the duration of the internship, as a member of the Discrete Optimization Unit, lead by Dr. Takanori Maehara. Plane tickets (round-trip), as well as a monthly living allowance will be provided.

For further information or to apply (join your resume in that case, **before the 15th of December, 2019**), please contact *both* jean-francois.baffier@riken.jp and florian.richoux@polytechnique.edu.

References

[1] Francesca Rossi, Peter van Beek, and Toby Walsh. *Handbook of Constraint Programming (Foundations of Artificial Intelligence)*. Elsevier Science Inc., 2006.

[2] Jean-Francois Puget. Constraint programming next challenge: Simplicity of use. In *Principles and Practice of Constraint Programming (CP'04)*, volume 3258, pages 5–8, 2004.

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[4] Peter M Maurer. A universal symmetry detection algorithm. *SpringerPlus*, 4(1):418, 2015.

[5] Giovanni Lo Bianco. *Estimating the number of solutions of cardinality constraints*. PhD thesis, École nationale supérieure Mines-Télécom Atlantique, 2019.

[6] Florian Richoux, Alberto Uriarte, and Jean-François Baffier. GHOST: A combinatorial optimization framework for real-time problems. *IEEE Transactions on Computational Intelligence and AI in Games*, 8(4):377–388, 2016.