Research Topic for the ParisTech/CSC PhD Program

Field: Information and Communication Sciences and Technologies

Subfield: Logic

Title: Proofs without Syntax

ParisTech School: Ecole Polytechnique

Advisor Name: Lutz Straßburger

Advisor Email: lutz@lix.polytechnique.fr

Advisor website: http://www.lix.polytechnique.fr/Labo/Lutz.Strassburger/

Lab: Laboratoire d'Informatique de l'École polytechnique (LIX)

Lab website: https://www.lix.polytechnique.fr/

Short description of possible research topics for a PhD:

Proof theory is a central area of theoretical computer science, as it can provide the foundations not only for logic programming and functional programming, but also for the formal verification of software. Yet, despite the crucial role played by formal proofs, we have no proper notion of proof identity telling us when two proofs are "the same". This is very different from other areas of mathematics, like group theory, where two groups are "the same" if they are isomorphic, or topology, where two spaces are "the same" if they are homeomorphic.

The problem is that proofs are usually presented by syntactic means, and depending on the chosen syntactic formalism, "the same" proof can look very different. In fact, one can say that at the current state of art, *proof theory is not a theory of proofs but a theory of proof systems*. This means that the first step must be to find ways to describe proofs independent from the proof systems. In other words, we need a "syntax-free" presentation of proofs.

A recent breakthrough in that direction is the notion *combinatorial proof* which forms a syntax-independent canonical proof representation. The main topic of this PhD will be to participate in the further development of combinatorial proofs, including: (1) extending the theory to richer logics, (2) translating between syntactic proofs and combinatorial proof, and (3) implementing tools using combinatorial proofs.

Required background of the student:

The successful candidate should have a good background in logic, and also some knowledge in one or more areas among the following: proof theory, combinatorics, graph theory, category theory.

A list of representative publications:

1. Lutz Straßburger. Combinatorial Flows and Proof Compression. Research Report RR-9048, Inria Saclay, 2017. URL: https://hal.inria.fr/hal-01498468

2. Lutz Straßburger. Combinatorial Flows and Their Normalisation. In *FSCD 2017 (LIPIcs)*, Dale Miller (Ed.), Vol. 84. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, 31:1–31:17.

3. Matteo Acclavio and Lutz Straßburger. From syntactic proofs to combinatorial proofs. In Didier Galmiche, Stephan Schulz, and Roberto Sebastiani, editors, *Automated Reasoning - 9th International Joint Conference, IJCAR 2018, Held as Part of the Federated Logic Conference, FloC 2018, Oxford, UK, July 14-17, 2018, Proceedings*, volume 10900, pages 481–497. Springer, 2018.

4. Novak Novakovic and Lutz Straßburger. On the power of substitution in the calculus of structures. *ACM Trans. Comp. Log. 16(3)*, 2015.

5. Lutz Straßburger. From deep inference to proof nets via cut elimination. *Journal of Logic and Computation 21 (4), 589–624*, 2009.