M2 LMFI

Proofs and programs: advanced topics

Linear Logic and Quantitative Semantics

Teachers:

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Organization

- Lectures:

  Wednesday 14h00-16h00

  Friday 14h00-16h00

- Exercices:

  integrated to the lectures.

- **Grading:**
  - **weekly homework** projects

Plan

- A foundational study of functional programs which builds on build on *proof theory* (Types, Curry-Howard isomorphism) and the theory of *lambda-calculus*, adopting *the* ***dynamic and quantitative view brought by Linear Logic.***

  - Focus first part: a **quantitative view in Operational Semantics**
  - Focus second prat: a **quantitative view in Denotational Semantics**
  - Openings towards active research topics: probabilistic (from which also quantum) programming

- Courses from LMFI first term we build on:
  - *Proof Theory*,
  - *Computability and Complexity*
- Connected to the MPRI course: Semantics of Programming Language (built on the model of Linear Logic)

Plan: first part (C. Faggian)

HANDS-ON

- Theoretical tools to study the operational properties of a system:
  - Rewrite Theory (rewriting=abstract form of program execution)
- Linear Logic and Proof-Nets.

- Bridging between lambda-calculus and functional programming:
  - Call-by-Value and Call-by Name, weak and lazy calculi.

- Beyond pure functional:
  - Probabilistic programming and Bayesian Inference:
    Probabilistic lambda calculi, Bayesian proof-nets

(Internships possible on operational aspects of probabilistic and quantum computation)

Plan: second part (G.Vanoni)

- Recap on the untyped lambda-calculus.
- The denotational semantics of untyped lambda-calculus, via intersection types.
- Soundness and adequacy.
- A quantitative view of denotational semantics: linear logic flavoured intersection types.
- Towards operational aspects: abstract machines and their complexity analysis.
- Semantics and verification of imperative programs: Hoare logic.
- Probabilistic extensions of intersection types.
- Probabilistic extensions of Hoare logic.

Thesis available in Lille with Patrick Baillot.

Resources

- Handbook of Linear Logic, available online
- Lecture notes on Proof Nets (by O. Laurent):
  https://perso.ens-lyon.fr/olivier.laurent/pn.pdf

- G. Winskel: Formal Semantics of Programming Languages.

- Hindley, Seldin: Lambda calculus and combinators: an introduction.

- Research papers and lecture notes given by the instructors.