Audition Poste MCF – LMF – Polytech Saclay

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May 21st, 2025

Quick Introduction

Ralph Sarkis – PhD at ENS de Lyon (2024) – post-doctoral fellow at UCL (London)

Education

’16–’19 Bachelor in Maths&CS @McGill

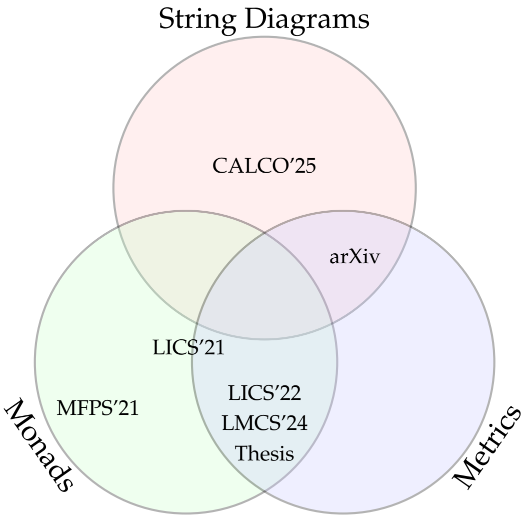
’19–’21 Master in CS @ENS de Lyon

’21–’24 PhD in CS @ENS de Lyon

Teaching

- +100h tutorials and +40h lectures
- Designed course and textbook
- Outreach activities (+100h)

Research



Outline

Teaching

Research

Past Teaching Activities

Title	CM	TD	Level	Size	University
Directed Reading (2025)	0	0	Bachelor	8	UCL
Semantics and Verification (2021–2023)	0	62	Master	15	ENS de Lyon
Proofs and Programs (2022–2023)	0	40	Master	15	ENS de Lyon
Category Theory (2019–2023)	40+	0	Bachelor+	10–20	McGill and ENS
Theory of Computation (2018)	0	0	Bachelor	$\geq$100	McGill
Total	**40+**	**102**			

- Composed tutorial sheets (exercises and solutions) for M1 students
- Designed a L3–M2 course on category theory and the associated textbook
- Supervised student-teachers for the category theory course
- Grading homeworks, exams, essays, and presentations
- Office hours (*permanence*)

Teaching at Polytech Saclay

I am interested in many courses in the *Informatique et Ingénierie Mathématique* cursus. Some of my favorites:

- Algorithmique I & II
- Analyse
- Fondements théoriques I & II
- Informatique quantique
- Informatique théorique
- MPRI and *prépa* courses

I wish to pursue the transformation of Polytech's classes with active learning.

- Projects and SAÉ: promote idependent research, collaboration, and time management
- Other novel pedagogical methods: think-pair-share, flipped classrooms, just-in-time teaching

I will foster an inclusive and diverse learning environment.

- Outreach activities to make CS accessible and disseminate academic values

Outline

Teaching

Research

Context: Program Equivalences and Distances

Example ([Neu51])

```
return fairCoin(H,T)
```

```
do
    x = biasedCoin(H,T)
    y = biasedCoin(H,T)
while (x == y)
return x
```

Context: Program Equivalences and Distances

Example ([Neu51])

```
return fairCoin(H,T)
```

```
do
    x = biasedCoin(H,T)
    y = biasedCoin(H,T)
while (x == y)
return x
```

As long as the bias is consistent and not total ($0\% < p < 100\%$), the two programs have the same behavior.

Context: Program Equivalences and Distances

Example (Guaranteed Termination)

```
return fairCoin(H,T)
```

```
i = 0
do
    i = i + 1
    x = biasedCoin(H,T)
    y = biasedCoin(H,T)
while (x == y) AND i <= 1000
return x
```

The second program is very close to being a fair coin flip.

Categorical Semantics

The goal of semantics:

$$\{\text{syntax}\} \Longleftrightarrow \{\text{semantics}\}$$

I have worked with

algebraic theories $\Longleftrightarrow$ monads	[MSV21; PS21; MSV22; MSV24; Sar24]
string diagrams $\Longleftrightarrow$ monoidal categories	[Lob+25; SZ25]

Quantitative Semantics

The semantics we are trying to axiomatize comes with a notion of distance, hence the syntax must also come with one.

Examples

The Hausdorff metric is a distance between sets (of nondeterministic choices).
The Hamming distance between lists/words.

Equational reasoning becomes quantitative by replacing $=$ with $=_\varepsilon$ [MPP16]:

$$x =_\varepsilon y \text{ means the distance between } x \text{ and } y \text{ is smaller than } \varepsilon$$

Goal

Deductive system to derive a semantic distance by manipulating syntax and $=_\varepsilon$.

Two Important Results in my Thesis

- The algebraic theory of convex algebras, modelling discrete probabilistic choices is well-known since [Sto49]:

$$x +_p x = x \qquad x +_p y = y +_{1-p} x \qquad (x +_q y) +_p z = x +_{pq} (y +_{\frac{p(1-q)}{1-pq}} z)$$

  It presents the monad of finitely supported distributions $\mathcal{D}$.
- Many distances were studied on $\mathcal{D}X$, e.g. Kantorovich, total variation, Kullback–Leibler divergence, etc. The first two were axiomatized with quantitative equations $=_\varepsilon$ in [MPP16].
- The theoretical framework of [MPP16] is not always applicable.

Two Important Results in my Thesis

- The Łukaszyk–Karmowski distance is not a metric and $+_p$ is not nonexpansive.
- Our theoretical framework [MSV22; MSV24] *does* apply, and we get a simple axiomatization by addding the following to convex algebras:

$$x =_{\varepsilon_1} y, x =_{\varepsilon_2} z \implies x =_{p\varepsilon_1+(1-p)\varepsilon_2} y +_p z.$$

- Our framework "always" applies. Given a monad M on **Set** that is axiomatized, any lifting of M to metric spaces can be axiomatized.
- Our framework also applied to generalised distances, e.g. pseudometrics, ultrametrics, probabilistic metrics, preorders, etc.

Research at LMF

A lot of members are working at the foundation of verification, especially in the themes *Calcul, langage et compilation* and *Preuves de programme*. I wish to develop foundations for quantitative verification with applications in mind.

Probabilistic Programming

- *Short term:* Searching for axiomatizations of distances in the literature.
- *Short term:* Contributing to categorical probability (see e.g. [Per24; LRS25]).
- *Long term:* Developing a (diagrammatic) language for quantitatively verified probabilistic programs. Taking inspiration from [Ava+25] and [BDGDL25].

Artificial Intelligence

- *??? term:* Enhancing existing categorical semantics of learning (e.g. with lenses [Cru+22]) to account for quantitative properties.

Research LMF

My research on string diagrams could lead to collaboration with members of QuaCS.

Quantitative Diagrammatic Reasoning

- *Short term:* First examples, maybe inspired by [KTW17; BMR19; HL21].
- *Long term:* Developing a diagrammatic language for quantitatively verified quantum programs.

For Teaching

- *Medium term:* Translating the resources [CG22] and reproducing the experiments [DC+23].

Merci !

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