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Column New Impulse

Bijections, broccolis and the brain

In this column, researchers who have been recently appointed to one of the Dutch mathematics institutes, introduce themselves.

Back in December 2021, when Daniel Valesin sent me an e-mail to ask whether I wanted to apply for a job in Groningen, I remember scrolling through the job post and realising that I satisfied exactly one of the ten requirements: 'Proficiency in Dutch or willingness to learn Dutch'. I had far from finished my PhD, none of my papers were published, and I had just made up my mind about extending my stay in academia with a two year postdoc. I was pretty confident in my Dutch proficiency, but maybe not confident enough to bag a faculty position in mathematics with. So, without expecting anything, I wrote my letters and hoped for the best. Now, a PhD graduation, a partial postdoc and a few months on the job later, I can confirm that it was indeed the best that I was hoping for.

Returning to your home university has many upsides, such as a strong, welcoming network across the whole department, an easy connection with the students because I was on the other side of that same classroom not so long ago, and a mug on the golden shelf reserved for faculty of my old 'studievereniging'. But it is not always rainbows and butterflies. Within a week of getting the offer, I had a nightmare about being called into my lecturer-gone-colleague's office to discuss my train wreck of a homework set from 2013, and whenever the seminar gets moved to a different room I risk getting a flashback to, say, a Linear Algebra 1 computer practical. Overall, returning to the University of Groningen has been an excellent choice though: the probability group is tight-knit and collegial, I thoroughly enjoy the interactions with the students and it has been very rewarding to (re-) connect with the Dutch research community.

My move to Groningen completed my westward lap around the world. I started here as a undergraduate student, where Daniel Valesin and Aernout van Enter first introduced me to random graphs during my bachelor project. I then moved to Cambridge, to take part in the one-year-long maths bootcamp that is called Part III. The program was all-consuming and it felt like a marathon at sprinting pace, but I never learned as much in a year, I met wonderful people, and it surely whipped me into shape for my PhD position in Oxford. There, I worked with Christina Goldschmidt, and under her supervision and as part of the

Oxford probability group, I further developed my appetite for randomness, graphs and random graphs. During those years, I also started working with Louigi Addario-Berry at McGill, who also became my postdoc advisor during my final stop in Montréal before returning to Groningen.

My research is in combinatorial probability and probabilistic combinatorics. (On Timothy Gowers' spectrum from theory builders to problem solvers, I am definitely more on the latter side.) I like finding cute sampling procedures for random structures that are somehow the correct encoding for the property that I want to study. This often means finding a new bijection or a new 'exploration procedure' of the random object that reveals everything you need and nothing too much. Once my coauthors and I find this sampling procedure, the analysis begins, and I really enjoy this mix of discrete puzzles and continuous machinery.

Let me highlight some more specific things that I am interested in. One line of research that I have been working on since the start of my PhD is universality in random trees and graphs. It is not a coincidence that branching rivers, the circulatory system in animals, trees in the forest and broccolis look remarkably similar when you squint your eyes. This is a consequence of the underlying randomness in the growth of these structures. The precise dynamics are different, but those differences have a negligible effect on the overall structure. In my research I prove results that make this rigorous; morally, I show what it takes to look like a broccoli. Sometimes I look at the structure as a whole, and show that any (critical) random graph from a particular family, as the number of vertices goes to infinity and the distances between vertices are appropriately rescaled, converges to a particular random fractal [5, 8]. (This is made rigorous by viewing a finite graph as a compact measured metric space, and equipping the space of compact measured metric spaces with the Gromov–Hausdorff–Prokhorov topology.) Other times, I am interested in more specific statistics, and I have obtained non-asymptotic, universal tail bounds on the height of random trees under very mild assumptions [1, 2]. With my first PhD student, Elaine Herrera, who is currently a lecturer in Winnipeg and moves to Groningen in October, we are going to further explore universality in directed graphs, building on some of my own doctoral work.

My interests have also expanded towards more combinatorial questions. (This was partly instigated by my friend Carla Groenland, who is an Assistant Professor in Delft and who I met during a seminar in Oxford, where my Dutchness was revealed to her by my Dopper bottle.) For example, with our coauthors, we managed to find the asymptotic number of sequences of length n that can occur as the degree sequence of a graph, by using a reformulation of the problem into a question about random walks [3]. (If this sounds mysterious to you, you should probably invite Carla or me to give a seminar talk...) With some other coauthors, we have since then also approached this question and relatable questions via another route, with a method that we call the Lévy–Khintchine technique, that allows one to asymptotically enumerate objects that possess a renewal structure [4, 6, 7]. This technique is a combinatorial implication of the probabilistic idea that infinitely divisible distributions are often best understood via their characteristic functions. Via this scheme we can find the asymptotics of a 'difficult' sequence by studying an easier related sequence. We feel that we have barely scratched the surface of this technique, and I am very excited to further explore its potential in the years to come.

My taste is pretty broad, so I also work on a plethora of other projects. (Well, as long as it involves randomness and graphs; in the words of Henry Ford: "A customer can have a car painted any colour he wants as long as it's black.") For example, I also have some ongoing work on large deviations of random graphs, reconstruction of random trees, convergence of random snakes, Gibbsian tree ensembles and Markov chains on the space of trees. Furthermore, in Groningen, I also joined CogniGron, which is an interdisciplinary centre with the aim to improve learning-based cognitive computing with materials-centred systems. The brain in rest is often believed to be at a critical point, which is where the link with my research comes in. Indeed, I hope to contribute to this fundamental research by connecting with, for example, material scientists and computer scientists, through our shared interest for random structures at or near criticality.

Overall, I am so happy to have found myself here, in the probability group, in CogniGron, at the University of Groningen and in the Dutch mathematical community. I cannot thank Daniel enough for that e-mail back in 2021 and his faith in me (and my Dutch proficiency). It is not always easy being part of a minority in STEM, but I am so fortunate to have found colleagues, mentors and friends that have propelled me forward in academia, and I hope that I will increasingly be in a position to play this role for the younger people around me.

References

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