LUCA AVENA Mathematical Institute

Random walks to explore Facebook or the brain

Facebook, city streets, even the brain - many complex systems can be analysed as a network of nodes and the links between them. Random walks through large networks bring their large-scale properties to light. Luca Avena's research aims for a better understanding of complex networks, such as brain scans or weaknesses in our banking system.

By Arnout Jaspers

LUCA AVENA studied mathematics in Italy, and came to Leiden for his PhD, which he obtained in 2010. After postdoc positions in Zürich and Berlin, he returned to Leiden, where he is now an assistant professor in Probability Theory.

Facebook has about a billion users, so it is a network with a billion nodes and hundreds of billions of links connecting them. The human brain is even much bigger than that. Researchers want to fathom structural properties of such huge networks. For many practical problems, it makes no sense to look at every node and link in a network. It is much more efficient to explore it with a random walk: start at an arbitrary node, and throw a dice to decide which link you will follow to the next node. There are many kinds of random walks. In his research, Luca Avena uses them as a tool kit, for instance to figure out how well-connected a network is. Recently, together with French mathematician Alexandre Gaudillière, he devised a new tool based on random walks to explore the architecture of a network. He calls it the 'random spanning rooted forest'. The roots of this forest form a subset of well-distributed nodes in the network under investigation. In a real-world network, for instance in an electricity grid, putting the power plants in place of the roots would render the most efficient energy distribution. Avena is further developing this new tool to address more real-world problems. He has recently started to interact with a group of engineers in Marseille, France, who need efficient algorithms for signal processing. Also, he started a collaboration with Diego Garlaschelli, a physicist from the Lorentz Institute, to analyse networks of banks. Analysing tightly connected communities in these networks reveals vulnerabilities in the financial system in case one of them goes bankrupt.

Avena: 'Random walk models have lots of real-world applications. You can also use them to model how prices evolve in the stock market, or how a virus spreads throughout a population. My work mainly concerns the mathematical foundations of these models. As is often the case in mathematics, new tools for real-world applications come out of this fundamental research.'