New clues on how networks such as Twitter are organized to respond to viral news

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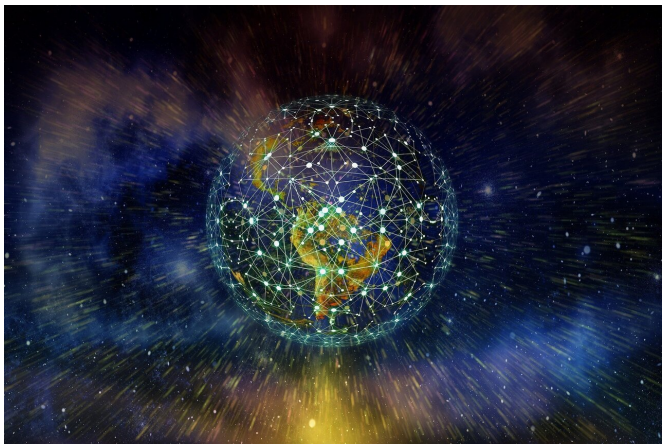

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Examples of complex systems exist everywhere. Neuron connections and protein–protein interactions are two systems of this type found in organisms, but complex systems also exist in cities, economic models, and even in social networks. The common denominator is that they are made up of many interrelated elements which can be represented and studied as a network.

For more than a decade, scientists have been studying the possibility of finding more than one type of structural organization within a single network, and this is the subject of the doctoral thesis defended by María José Palazzi, as part of the UOC's doctoral program in Network and Information Technologies.

"The idea was to identify and explore the existence of more than one structural pattern within a single network. We wanted to see to what degree this could be an anecdotal or frequent event in real-life networks, and to try to understand some of the mechanisms that cause this type of structure to emerge," explained Palazzi, a researcher with the research group Complex Systems (CoSIN3) at the UOC's Internet Interdisciplinary Institute (IN3). Palazzi's thesis was supervised by Javier Borge, lead researcher of CoSIN3, and co-supervised by fellow researcher Albert Solé, professor at the Faculty of Computer Science, Multimedia and Telecommunications.

The researchers analyzed several real-life cases. One of these involves patterns of interaction between users and so-called "memes" in online environments, and the way these change over time. Specifically, the researchers focused on Twitter and used hashtags to help them analyze these data.

Palazzi studied on Twitter, among other events, the 2019 Spanish general elections and the Charlie Hebdo attack in 2015. For the elections, she retrieved over 30 million tweets from more than 1.8 million users and more than 124,000 hashtags from among all the content posted online between 12 April and 6 May 2019. For the Twitter activity linked to the Charlie Hebdo attack, she looked at over six million tweets from more than 2 million users and more than 102,000 hashtags posted on 8 and 9 January 2015.

"The system tends to be organized in a modular structure, with an internal hierarchy that normally responds to the different interests of users," said Palazzi. For example, when a news item goes viral, the system reorganizes itself into a nested structure in which the elements with few connections ("specialists") form subsets with other elements with more connections ("generalists").

The specialists, who are less active on the social network, only interact with the generalists, but the generalists, who are more active and post tweets more frequently, may also interact with other generalists. Once interest in the event has waned, the system reverts to its normal modular organization.

Another of the real-life cases involved the study of

the patterns that emerge from interactions between software developers and the data files that make up a free software project. "We found that the patterns evolve into a block or modular structure and that, as the project progresses, these modules are organized internally in a hierarchical way," explained Palazzi.

A breakthrough in network analysis

The contribution of this thesis to the field of study is a breakthrough in the structural analysis of networks. "There was a small gap in our understanding of the conditions required for the coexistence of macro-scale, network-wide patterns such as nestedness, and modularity, which is mesoscale, the groups that make up the network," summed up Palazzi.

The study has already been published in four scientific journals: *Scientific Reports*, *Communications in Nonlinear Science and Numerical Simulation*, *Journal of the Royal Society Interface* and, most recently, in *Nature Communications*.

More information: María J. Palazzi et al. Online division of labor: emergent structures in Open Source Software, *Scientific Reports* (2019). DOI: 10.1038/s41598-019-50463-y

Manuel S. Mariani et al. Absence of a resolution limit in in-block nestedness, *Communications in Nonlinear Science and Numerical Simulation* (2020). DOI: 10.1016/j.cnsns.2020.105545

M. J. Palazzi et al. Macro- and mesoscale pattern interdependencies in complex networks, *Journal of The Royal Society Interface* (2019). DOI: 10.1098/rsif.2019.0553

María J. Palazzi et al. An ecological approach to structural flexibility in online communication systems, *Nature Communications* (2021). DOI: 10.1038/s41467-021-22184-2

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