Hybrid SORS/Life Session: The physics of epidemic spreading

Objectives

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Abstract: Reaction–diffusion processes have been widely used to study dynamical processes in epidemics and ecology in networked metapopulations. In the context of epidemics, reaction processes are understood as contagions within each subpopulation (patch), while diffusion represents the mobility of individuals between patches. Recently, the characteristics of human mobility, such as its recurrent nature, have been proven crucial to understand the phase transition to endemic epidemic states. Here, by developing a framework able to cope with the elementary epidemic processes, the spatial distribution of populations and the commuting mobility patterns, we discover three different critical regimes of the epidemic incidence as a function of these parameters. Interestingly, we reveal a regime of the reaction–diffussion process in which, counter-intuitively, mobility is detrimental to the spread of disease. We analytically determine the precise conditions for the emergence of any of the three possible critical regimes in real and synthetic networks. Moreover, we propose to represent the heterogeneity in the composition of the metapopulations as layers in a multiplex network, where nodes would correspond to geographical areas and layers account for the mobility patterns of agents of the same class. We analyze classical epidemic models within this framework and obtain an excellent agreement with extensive Monte Carlo simulations. This agreement allows us to derive analytical expressions of the epidemic threshold and to face the challenge of characterizing a real multiplex metapopulation, the city of Medellín in Colombia, where different recurrent mobility patterns are observed depending on the socioeconomic class of the agents. Our framework allows us to unveil the geographical location of those patches that trigger the epidemic state at the critical point. A careful exploration reveals that social mixing between classes and mobility crucially determines these critical patches and, more importantly, it can produce abrupt changes of the critical properties of the epidemic onset. Finally, we will briefly revise a taylored model for the spreading of COVID-19 in Spain.

from the University of Barcelona (1996), he is Professor of the Department of Computer Engineering and Mathematics (DEIM) of the Rovira i Virgili University (URV) since 2010. He is also External Faculty of the Complexity Science Hub in Vienna, since 2017, and Chief Scientist of Complex Systems Science at Pacific Northwest National Laboratory (PNNL, USA). He has been a visiting researcher at: Lawrence Berkeley Laboratory (LBL) and UC Berkeley, University of Oxford, ISI Foundation of Turin, Max-Planck-Institut of Dresden, and Institute Universitaire Kurt Bösch from Switzerland. His scientific career has focused on the study of complex network systems, a multidisciplinary field, which he has approached from the point of view of physics and computation. Publications on medicine, epidemiology, biology, economics, urban science, technological systems, and social sciences abound in his curriculum. The result of his research has been the publication of more than 255 articles in international journals, including: Nature, The Lancet, Nature Physics, Science Advances, Physical Review X, PNAS USA, etc. These articles have received 36,500 citations according to Google Scholar, with an H index of 74. He has been the researcher in 47 research projects, 40 as Principal Investigator, including two EU FP7 and one from the James S. McDonnell Foundation. He is editor of the journal Physical Review E, published by the American Physical Society, being responsible for the Interdisciplinary Physics section, as well as the Journal of Complex Networks and the Journal of Computational Social Science. He has served as an evaluator for national and international scientific projects, including ERC projects. He has supervised 13 finished doctoral theses and 4 in progress. As scientific recognitions, the appointments stand out as Fellow of the Americal Physical Society (2018), Fellow of the Network Science Society (2020), and the Mathematics and Society Award of the Ferran Sunyer i Balaguer Foundation (2020), ICREA Academia (2011 and 2017), Scientific award recognition“Ciutat de Tarragona” (2022), and Narcís Monturiol Medal to scientific merit (2022). His performance has been recognized by the Government of the Generalitat proposing him as a member of the COVID-19 Advisory Committee in Catalonia.

Speakers

Speaker: Àlex Arenas, Professor of the Department of Computer Engineering and Mathematics (DEIM) of the Rovira i Virgili University
Hosts: Alfonso Valencia, Computational Biology Life Sciences Group Director and Miguel Ponce de León, Computational Biology Life Sciences Group

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