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Comment

Pattern transition phenomena in spatial modeling of infectious diseases ☆
Comment on "Pattern transitions in spatial epidemics: Mechanisms and emergent properties" by Gui-Quan Sun et al.

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Infectious disease, ever a significant worldwide problem, has been a major force in shaping world history. We saw this in the 2009 H1N1 outbreak and subsequent pandemic, and again in the worldwide spread of SARS in 2003 [1]. More recently, humanity has been put at significant risk on an international scale by the emergence of old or completely new diseases enhanced by the efficiency, speed, and reach of modern transport networks. As a result, the spread of communicable diseases has accelerated not only by proliferation of disease within discrete populations through infectious contacts but also through the multiple spatial scales created by human mobility [5].

Spatial structures play an important role in describing the geographic spread of emergent infectious diseases. Reaction-diffusions, which describe a combination of local exponential growth and diffusive dispersal, have been proposed to study dynamics of infectious diseases [3]. When reaction–diffusion equation models are used to design effective prevention and control strategies, additional spatial factors such as immigration, vaccination, individual movements, and quarantine may also be taken into account [3].

Many reaction-diffusion systems exhibit constant velocity epidemic wave fronts and pattern formation phenomena. Traveling wave solutions of spatial epidemic models represent the transition process of an outbreak from different equilibria; for example, from an initial disease-free equilibrium to another disease-free state. They also describe the propagation of a disease as a wave with a fixed shape and a fixed speed. Thus, the study of traveling wave solutions provides important insight into the spatial patterns of invading diseases [2,6,7].

Pattern formation is representative of orderly distribution of individuals in both time and space. Sun et al. [4] survey pattern transition of infectious diseases across spatial scales and examine the underlying mechanisms, and related emergent properties. Their review is impressive and clearly written, providing a comprehensive account of models that can produce pattern formations and mechanisms that promote spatial patterns. Two particularly relevant mathematical methods to model the spatial processes, reaction-diffusion equations and cellular automata, are carefully discussed. Cellular automata (CA) have been employed to describe various interactions in the real world, and they

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effectively reveal the evolution of the systems. Transitions between the two common types of patterns, stationary patterns and spatio-temporal patterns, are investigated in a number of epidemiological systems. Sun et al. [4] are interested in stationary patterns corresponding to the stable solutions of model equations and spatio-temporal patterns representing (i) quasi-periodic or oscillatory waves, (ii) temporal or spatio-temporal chaos, or even (iii) turbulence.

In that context, the focus is put on the underlying causes of such pattern transitions in various spatially explicit settings. Sun et al. [4] examine a number of key mechanisms of pattern transitions, including 1) spatial heterogeneity, 2) seasonality and noise, and 3) human behavior. It is found that reaction-diffusion models with spatial heterogeneity exhibit dynamic phenomena such as epidemic wavefronts observed in the real world. Sun et al. [4] also demonstrate spiral waves in periodic models that mimic seasonal changes of contact rate. Human behavior becomes a more significant factor in disease dynamics, particularly when preventive measures such as immunization are available. Further, the spatial structure of the population and human mobility patterns introduce pattern transitions across spatial scales. Sun et al. [4] also provide interpretations of pattern transitions as potential early warning indicators of an imminent outbreak.

The review paper highlights recent research on pattern transitions in spatial epidemics and their underlying mechanisms. As suggested by Sun et al. [4], directions forward to improve the realism and applicability of the reaction-diffusion models include incorporating space inhomogeneities, mixed diffusion models, and nonlocal models. Finally, advances in big-data technologies provide a new promising opportunity to apply reaction-diffusion equations to forecast infectious disease activities based on huge amounts of healthcare related data from online social networks and other emerging fields such as health informatics [8].

References

[1] Belik V, Geisel T, Brockmann D. Natural human mobility patterns and spatial spread of infectious diseases. Phys Rev X 2011;1:011001.
[2] Castillo-Chavez C, Li B, Wang H. Some recent developments on linear determinacy. Math Biosci Eng 2013;10:1419–36.
[3] Real L, Biek R. Spatial dynamics and genetics of infectious diseases on heterogeneous landscapes. J R Soc Interface 2007;4:935–48.
[4] Sun G-Q, et al. Pattern transitions in spatial epidemics: mechanisms and emergent properties. Phys Life Rev 2016;19:43–73. http://dx.doi.org/10.1016/j.plrev.2016.08.002 [in this issue].
[5] Tatem AJ, Rogers DJ, Hay SI. Global transport networks and infectious disease spread. Adv Parasitol 2006;62:293–343.
[6] Wang H, Wang X-S. Traveling wave phenomena in a Kermack–McKendrick SIR model. J Dyn Differ Equ 2016;28:143–66.
[7] Wang X-S, Wang H, Wu J. Traveling waves of diffusive predator–prey systems: disease outbreak propagation. Discrete Contin Dyn Syst, Ser A 2012;32:3303–24.
[8] Wang F, Wang H, Xu K, Raymond R, Chon J, Fuller S, et al. Regional level influenza study with geo-tagged Twitter data. J Med Syst 2016;40:189.