Mathematical Methods and Models in Biosciences
June 15–20, 2025, Sofia, Bulgaria
https://biomath.math.bas.bg/biomath/index.php/bmcs

Modeling infectious disease dynamics with network-based approaches for enhanced epidemic preparedness

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The spread of infectious diseases is inherently influenced by the underlying network of interactions within a population. Traditional compartmental models like SIR often fail to capture the complex disease transmission dynamics in heterogeneous settings. This study presents a modified SIR model that integrates network-based approaches, leveraging Forman-Ricci Curvature (FRC) for interaction in networks' local connectivity and structure. By incorporating network characteristics, the model captures variations in disease spread due to network topology, emphasizing regions of high curvature for targeted intervention. We analyze the stability of both Disease-Free and Endemic Equilibria, revealing critical thresholds for epidemic outbreaks. The incorporation of FRC enables a more nuanced understanding of transmission heterogeneities, thereby enhancing the predictive accuracy of disease models. The study underscores the utility of network theory in identifying potential super-spreader nodes and bottlenecks, offering a powerful framework for optimizing public health strategies aimed at epidemic preparedness and intervention.

Keywords: infectious disease modeling, networked-based SIR model, Forman-Ricci Curvature (FRC), complex network analysis, epidemic preparedness

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