frontiers | Frontiers in Physics

TYPE Editorial
PUBLISHED 08 November 2024
DOI 10.3389/fphy.2024.1506990

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Matjaž Perc,
University of Maribor, Slovenia

*CORRESPONDENCE
Ayse Humeyra Bilge,
ayse.bilge@khas.edu.tr
Ayse Peker-Dobie,
pdobie@itu.edu.tr
Dimiter Prodanov,
dimiter.prodanov@imec.be

RECEIVED 06 October 2024
ACCEPTED 09 October 2024
PUBLISHED 08 November 2024

CITATION
Bilge AH, Peker-Dobie A, Severin I, Piqueira JRC, Bellingeri M and Prodanov D (2024) Editorial: Compartmental models for social interactions.
Front. Phys. 12:1506990.
doi: 10.3389/fphy.2024.1506990

Editorial: Compartmental models for social interactions

Ayse Humeyra Bilge[1]*, Ayse Peker-Dobie[2]*, Irina Severin[3], José Roberto Castilho Piqueira[4], Michele Bellingeri[5] and Dimiter Prodanov[6,7]*

[1]Department of Industrial Engineering, Faulty of Engineering and Natural Sciences, Kadir Has University, Istanbul, Türkiye, [2]Department of Mathematics Engineering, Faculty of Science and Letters, Istanbul Technical University, Istanbul, Türkiye, [3]Faculty of Industrial Engineering and Robotics, National University of Science and Technology Politehnica Bucharest, Bucharest, Romania, [4]Control Engineering Department, University of São Paulo, São Paulo, SP, Brazil, [5]Dip. Scienze Matematiche, Fisiche e Informatiche, Università di Parma, Parma, Emilia-Romagna, Italy, [6]Environment, Health and Safety, IMEC, Leuven, Belgium, [7]PAML-LN, IICT, Bulgarian Academy of Sciences, Sofia, Bulgaria

KEYWORDS

demographics, epidemic models, information propagation, social networks, social networks and communities

Editorial on the Research Topic
Compartmental models for social interactions

1 Introduction

Compartmental models have served as a foundational framework in epidemiology since the landmark work of Kermack and McKendrick in the 1920s. Although originally formulated as systems of partial differential equations, models in the form of ordinary differential equations corresponding to a special type of kernel are widely used today. This Research Topic aims to explore the diverse applications of compartmental models in understanding social interactions, information spread, and behavioral dynamics beyond traditional epidemiological contexts.

2 Historical context and theoretical framework

Compartmental models categorize populations into distinct groups—each representing a specific stage in disease transmission—enabling researchers to systematically analyze and predict epidemic behaviors. These mathematical models simplify the complex interactions inherent in real-world populations, providing actionable insights into the dynamics of disease spread.

The adaptability of compartment models has allowed for their application across various fields, including sociology, psychology, and even computer science. Beyond infectious diseases, these models are instrumental in studying phenomena such as rumor propagation, fake news spreading, social behavior, substance abuse, and peer group interactions.

Incorporating network topology into compartmental models has further enhanced our understanding of how social structures influence the dynamics of epidemic spread and social behaviors. The following articles in this Research Topic illustrate recent advancements and applications of compartment models in the context of social interactions.

3 Contributing articles

3.1 Forecasting infections with spatio-temporal graph neural networks: a case study of the dutch SARS-CoV-2 spread

This article focuses on forecasting SARS-Cov-2 infections in the Netherlands using a novel spatio-temporal graph neural network (GNN) model. The authors develop a detailed municipality-level COVID-19 dataset that includes demographics and inter-municipality interactions. The GNN model leverages temporal dynamics and spatial relationships to predict infection rates 1 week ahead. Experimental results show that this approach outperforms traditional forecasting methods, highlighting the effectiveness of integrating graph-based techniques in epidemic prediction (Croft et al.).

Key Contributions:

- Municipality-Level COVID-19 Dataset: Developed a comprehensive dataset containing municipality-level COVID-19 statistics, demographics, and inter-municipality interaction data.
- Novel Spatiotemporal GNN Model: Created an innovative spatio-temporal GNN model that captures temporal dynamics and spatial relationships for predicting SARS-Cov-2 infections 1 week ahead.
- Performance Evaluation: Demonstrated that the proposed GNN model outperforms traditional baselines in forecasting accuracy on the developed dataset.

4 Competitive information propagation considering local-global prevalence on multi-layer interconnected networks

This article presents a novel competitive information propagation model designed for multi-layer interconnected networks, addressing the complex dynamics of information spread in online social networks (OSNs). It highlights how both positive and negative information compete for attention and influence, with individual behaviors shaped by local and global information trends. The study mathematically analyzes the model's dynamics, calculates the basic reproduction number, and establishes stability conditions for different equilibria. It also formulates an optimal control strategy to manage the spread of negative information while minimizing costs (Cao et al.).

Key Contributions:

- Competitive Information Propagation Model: Developed a model that captures the coexistence of positive and negative information within multi-layer interconnected networks, reflecting real-world complexity.
- Incorporation of Individual Herd Behavior: Introduced a compartmental model where individual tendencies to spread information are influenced by both local and global prevalence, enhancing understanding of adaptive behaviors in information dynamics.
- Stability Analysis: Provided a rigorous mathematical foundation by calculating the basic reproduction number and using Lyapunov theory to discuss the stability of information-free and endemic equilibria.
- Optimal Control Framework: Formulated an optimization problem to effectively suppress negative information propagation, balancing control costs with propagation dynamics, and derived solutions to enhance practical decision-making in resource management.

5 Research on the dynamic spread of information in social networks based on relationship strength theory and feedback mechanism

This study introduces the DNIRep model, a novel dynamic network representation framework designed to enhance the modeling of rumor propagation in social networks. Acknowledging the limitations of existing static representation methods, DNIRep effectively captures the temporal dynamics and the complex interplay between explicit and implicit relationships among users. The model incorporates a feedback mechanism to improve the performance of node representations and demonstrates how trust levels and interactive behaviors shape public opinion dynamics (Zhang et al.).

Key Contributions:

- Dynamic Network Representation Model (DNIRep): Developed a new framework that integrates explicit and implicit relationships to more accurately represent information propagation in dynamic networks.
- Feedback Mechanism: Introduced a novel feedback system that enhances the updating of node representations, improving overall network representation performance.
- Alignment with Real-World Dynamics: Established a model that aligns more closely with real-world social networks, addressing the unique characteristics of rumor propagation and public opinion dynamics.
- Experimental Validation: Extensive simulations were conducted demonstrating that higher trust levels stabilize group opinions and that certain user interactions, including novelty of topics and opinion leaders, significantly influence public sentiment evolution.

6 Building a network with assortative mixing starting from preference functions, with application to the spread of epidemics

This study explores the dynamics of epidemic spread on networks characterized by second-order properties, specifically focusing on assortative mixing—where nodes connect preferentially based on their degrees. The authors propose a stochastic algorithm to construct networks that reflect real human connections, enhancing the understanding of how these structures influence the spread of infectious diseases. The research examines the impact of these networks on epidemic trajectories and evaluates whether the spread of disease can be predicted using readily observable data (Romanescu).

Key Contributions:

- Stochastic Network Construction: Developed a flexible algorithm for constructing networks based on individual preferences for connection, allowing for the creation of diverse assortative network profiles.
- Marginal Degree Preference: Introduced a method to derive the marginal degree preference from a general preference function, accommodating multiple external factors influencing connections.
- Epidemic Dynamics Simulation: Conducted simulations to analyze epidemic curves and overall epidemic sizes across various network types, supporting the hypothesis that the effective reproductive number can be predicted as a function of the susceptible population fraction over time.
- Guidance for Future Research: Provided a framework for further theoretical investigations into the effects of network structures on epidemic spread, emphasizing the relevance of second-order network properties in epidemiological modeling.

7 Exponential series approximation of the SIR epidemiological model

From a theoretical standpoint, the primary contribution of the article is the derivation of an infinite exponential, Dirichlet, series for the model variables, which are interrelated by logarithmic and exponential transformations to the R-variable. The finite truncation of the series results in a Prony approximation, which can be interpreted as a sequence of coupled exponential relaxation processes, each with a distinct timescale (Prodanov).

Key Contributions:

- A numerical Newton-Raphson approximation scheme for the R-variable is derived and compared to the parametric solution.
- The proposed numerical method is compared to the double exponential (DE) nonlinear approximate analytic solution, which reveals two coupled timescales: a relaxation timescale, determined by the ratio of the model's time constants, and an excitation timescale, dictated by the population size.
- The DE solution is applied to estimate model parameters for a well-known epidemiological dataset—the boarding school flu outbreak.

8 Conclusion

This Research Topic presents valuable insights into the application of compartment models beyond traditional epidemiology, focusing on their role in understanding social interactions and information dynamics. The featured articles explore various innovative approaches, including spatiotemporal graph neural networks and dynamic network representations, which enhance our comprehension of how diseases and information spread through networks.

By examining factors such as assortative mixing and individual preferences in network connections, these studies highlight the importance of network structure in shaping epidemic dynamics and social behavior. The integration of feedback mechanisms and relationship strength theory further enriches our understanding of these complex processes.

Nowadays real-world social networks hold great potential, especially as recent technological advancements have simplified the Research Topic of large-scale data on social interactions. This includes longitudinal information on physical proximity, high-resolution GPS data, and face-to-face interactions among individuals. These developments have enabled the construction of social networks in a variety of real-world settings with significant epidemiological relevance, such as schools, museums, and hospitals. Overall, this Research Topic of research lays the groundwork for future investigations and emphasizes the relevance of compartmental models in both public health and social sciences. It invites further exploration into the dynamics of interconnected systems, fostering a deeper understanding of the challenges we face in managing public health and information dissemination.

Author contributions

AB: Writing–review and editing. AP-D: Conceptualization, Investigation, Writing–original draft, Writing–review and editing. IS: Writing–review and editing. JP: Writing–review and editing. MB: Writing–review and editing. DP: Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research is partially funded under the National Recovery and Resilience Plan (NRRP), and Mission 4 Component 2 Investment 1.5—Call for tender No. 3277 of 30/12/2021 of Italian Ministry of University and Research funded by the European Union—NextGenerationEU Award Number: Project code ECS00000033, Concession Decree No. 1052 of 23/06/2022 adopted by the Italian Ministry.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

10.3389/fphy.2024.1506990

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.