A stochastic heterogeneous node-based generalized SIR model in switching network for COVID-19

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Abstract. In this paper, a generalized susceptible-infected-recovered (SIR) epidemic model in switching network is proposed to investigate COVID-19, which is an effective approach to the understanding of the impact of the structure of the propagation network on the epidemics of COVID-19. In order to analyse the effects of the policy change during COVID-19, a Bernoulli random variable are given to represent the switching connections in the propagation network of viruses. Also, the multiplicative noise terms are considered into the disease transmission coefficient to establish a stochastic model. Mathematically, the reproduction number is given to govern the stochastic dynamics of the proposed model. Some qualitative properties of the model are derived, including the existence, uniqueness and boundedness of a nonnegative solution and extinction in probability of the disease. Finally, the epidemic data are applied to demonstrate the validity of the derived results and the availability of the proposed models.

Introduction

The rapid spread of COVID-19 globally is the cause of panic and billions of dollars in losses and some public policies have been implemented to contain the spread of the virus. It is highly significant to establish mathematical models to describe the spread of the pandemic. In order to gain a deep insight on the effect of network structures on the disease propagation, some continuous-time node-based epidemic models including SIS and SIR [1] models have been investigated. Furthermore, the propagation network of viruses is not static during the spread of COVID-19. Therefore, a node-based model in switching network is proposed in this paper, in which a Bernoulli random variable is used to represent the switching connection behavior. Also, in this paper, the environmentally perturbed system is established by stochastically perturbing some system parameters with white noise [2, 3]. By using the proposed model, the confirmed, recovered, quarantined and death cases of Italy and their corresponding fitted curves are shown in Fig. 1.

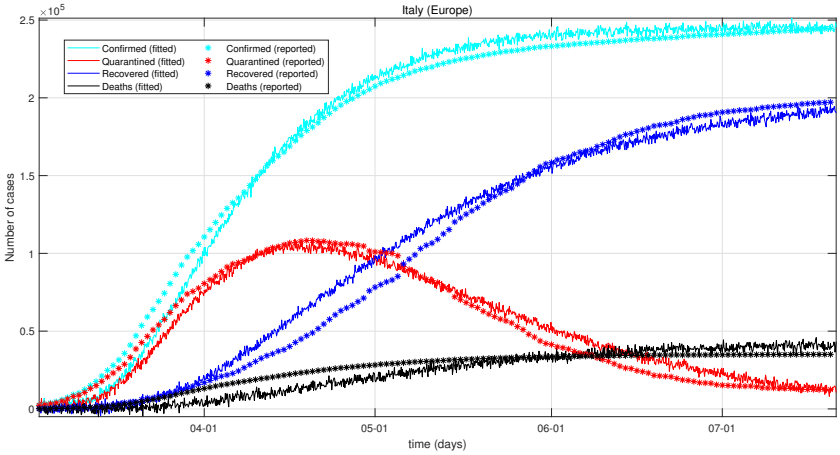

Figure 1: The confirmed, recovered, quarantined and death cases of Italy and their corresponding fitted curves.

Results and discussion

In this paper, a heterogeneous node-based generalized SIR model in switching network for COVID-19 is established and investigated and the parameters of the proposed model is identified by using the COVID-19 data. In the proposed stochastic model, in order to represent the policy change during COVID-19, a Bernoulli random variable is introduced to describe the switching connections in the propagation network of viruses. Also, the effects of environmental fluctuations are also considered by introducing the multiplicative noise terms into the growth equations. Furthermore, the nonlinear incidence rate is applied in the system to model the effects of intervention strategies. Then, some qualitative properties of the model are analyzed. Finally, some numerical results by using the COVID-19 data to demonstrate the validity of the derived results and the availability of the proposed models.

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