Preface

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It has been now more than 20 months since the first incident of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) was reported in Wuhan, China. Largely due to the high connectedness in the twenty-first century, the disease has since spread quickly and widely with the result that most of the world is now in the grip of this global pandemic. It is not an exaggeration to say that this unprecedented pandemic has turned the world upside down. Almost 3% of the world's population has been infected and more than 4.6 million people have died worldwide in repeated waves and, due to the imposition of restrictive measures, the economies of most countries have been severely disrupted. In the long term, systemic and widespread vaccination is believed to be the only

method to achieve herd immunity in order that lives can return to normal and future deaths can be prevented.

Although there has been intense research into many aspects of the COVID-19 pandemic over the past year and a half, many subtleties and challenges remain to be unfolded and understood. In this context, accurate modeling and analysis are important—and perhaps even imperative—to analyze and predict the evolution and impact of the disease and further provide meaningful information for the policy makers. Control measures such as vaccinations as well as non-pharmaceutical interventions (NPI) including quarantines, social distancing and mobility restrictions can also benefit from guidance provided by careful predictive analyses. We are hence pleased to present this Special Issue of Nonlinear Dynamics which brings together some very relevant papers on modeling, analysis and control of the COVID-19 pandemic.

It should be noted that mathematical modeling of epidemics is not new; the standard models that are used today (such as the Susceptible, Exposed, Infectious, Recovered, known as SEIR) in fact date back to the last century. However, the systematic collection of large quantities of data, their accessibility to the global research community, the powerful computational tools and easy access to published research has spurred an extraordinary research interest in this area in the short year or so that we have been targeting this scientific challenge. Hence, in the midst of this

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tragedy, researchers have had an opportunity to develop much more accurate models to guide the policy decisions in order to save lives and have positive impact.

The principal theme of many papers in this Special Issue is the refinement of the mathematical models in order to provide a better explanation for the data. In particular, the effect of government policies is analyzed in China [1], India [2] and multiple countries [3], as well as the effect of social distancing [4]. It is well known that comorbidities are a significant factor in determining the potential for serious illness for infected patients; this problem is modeled with nonlinear analysis in [5, 6]. Different regions of a country can have varying dynamics as well as interactions which can be analyzed by spatially distributed models. This problem is considered in [7, 8] for China and Italy, respectively. Other interesting model refinements include time-varying models [9], time delays [10] and stochasticity [11, 12].

Unfortunately, although many people recover when infected with mild symptoms, deaths have also happened at a much larger rate than for other common infections like the common influenza. The number of deaths is strongly correlated with the inability of hospitals to cope with the large number of patients and obviously depends on the country's inherent medical infrastructure and the rate of infections. Hence, much of the COVID-19 control strategy has been to slow down the infection rate, so that the number of patients who are very sick and need to be admitted at any time is less than the hospital capacity. This problem is analyzed in [13] which includes hospital infrastructure in their models.

Accurate estimation of parameters is essential for models built making use of field data. This problem is considered in [7, 14, 15, 16]. As we know, the typical pandemic dynamics involve successive waves, which, with appropriate measures, will slowly die out. As a reminder, the Spanish flu pandemic of 1918 went through four significant waves before it died down. It is hence of high interest to model the past and future waves of COVID-19, a topic thoroughly analyzed in [15, 17, 18]. A potential scheme is suggested in [19] to treat COVID-19 under possible analysis on 2019-nCoV. The evolution of the second wave of COVID-19 from six different countries is predicted in [20]. In [21] it is suggested that patient's symptoms (clinical symptoms and features) can be helpful to

distinguish infected COVID-19 cases by using the non-dominated sorting genetic algorithm (NSGA-II) within the proposed predictive model. In [22] it is confirmed that a combination of synchronized NPIs (the travel restrictions, the social distancing and the infection isolation) prevented 93.7% of SARS-CoV-2 infections. In [23] the first and second waves of COVID-19 are discussed based on data from four countries, and a potential scheme is suggested to control the pandemic. In [24], the impact of environmental stresses on the frequent waves of COVID19 is predicted making use of ANN (artificial neural networks) series.

The speed and evolution of mutation of SARS-CoV-2 virus are an important factor, while we deploy strategies for the future. In fact, as we write this editorial, the Delta variant has become the biggest and most virulent form and the Mu variant is emerging. In [25], a dataset of RNA sequences is analyzed to shed light on the evolution of the virus and [26] examines the impact of mutation cycles on spreading dynamics.

The Guest Editors sincerely hope that the selected papers, which underwent a rigorous review process, will turn out to be useful and inspiring for researchers interested in this rapidly growing area that is no longer restricted to epidemiology as it greatly benefits from a multi-disciplinary approach where the theory and tools of Nonlinear Dynamics play a major role.

Guest Editors of the Special Issue

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