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Editorial

Second special section on systems and control research efforts against COVID-19 and future pandemics

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More than one year after when the World Health Organization (WHO) declared the novel coronavirus outbreak a public health emergency in the highest level of alarm (30 January 2020), we are still in a major public health threat, and many countries continue imposing self-isolation and quarantine measures. As per 25 March 2021, there have been 123,636,852 COVID-19 infections and 2,721,891 deaths worldwide. While there have been significant improvements, with several vaccines approved by the Food and Drug Administration (FDA) in the United States, the European Medicines Agency (EMA), and other entities, the virus has started to mutate worldwide, increasing the threat not only to the elderly but to the young. For example, new variants such as the B.1.1.7 in the UK and B.1.351 in South Africa are more resistant to neutralization by convalescent plasma and vaccine, as well as more transmissible than pre-existing SARS-CoV-2 variants and may result in more severe illness. Thus, further efforts by the scientific community are needed to tackle the COVID-19 pandemic. This second special section includes ten articles contributing systems and control theory analysis towards a better understanding of the current pandemic, and potentially impacting responses to this and future pandemics.

The first paper is entitled **“Universal Features of Epidemic Models Under Social Distancing Guidelines”** by Mahdiar Sadeghi, James M. Greene, and Eduardo D. Sontag. The authors highlight social distancing as a form of Non-Pharmaceutical Intervention (NPI), and examine various policies and their impact on disease progression. Computational results show that combining a single period of social distancing with periodic relaxation appears to significantly reduce the peak of the infected population, while simultaneously delaying the necessary start time of the strict distancing period. Results in this article pave the way for tailoring social distancing guidelines in future pandemics.

The second article is a tutorial paper entitled **“Structural Identifiability and Observability of Compartmental Models of the COVID-19 Pandemic”** by Gemma Massonis, Julio R. Banga, and Alejandro F. Villaverde. This survey uncovers the structural identifiability and observability of 36 different SIR and SEIR-type model structures proposed in the literature. Considering a wide array of plausible choices of measured outputs and time-varying parameters leads to 255 different model versions which are classified according to their structural identifiability and observability. These analyses assess the potential and limitations of parameter fitting given the available knowledge and measurements, as well as the models’ ability to provide reliable information.

The third article, authored by João P. Hespanha, Raphael Chinchilla, Ramon R. Costa, Murat K. Erdal, and Guosong Yang, is entitled **“Forecasting COVID-19 Cases Based on a Parameter-Varying Stochastic SIR Model”**. The authors show that it is possible to construct reliable forecasts for the evolution of an epidemic purely from the time series of new cases and deaths. In the presence of asymptomatic cases, SIR-type models include internal parameters and states that cannot be uniquely identified solely based on measurements of new cases and deaths, but it is shown that this does not preclude the construction of reliable forecasts for future values of these states. The results in this article are validated on an extensive COVID-19 dataset covering the period from March through December 2020 in 144 regions around the globe.

Also focused on forecasting COVID-19 at the epidemiological level is the fourth paper, entitled **“On an interval prediction of COVID-19 development based on a SEIR epidemic model”** by Denis Efimov and Rosane Ushirobira. This paper considers a new discrete-time SEIR epidemic model used to predict the influence of quarantine on the SARS-CoV-2 outbreak in France, Italy, Spain, Germany, Brazil, Russia, New York State, and China. The authors propose an interval predictor method to analyze the COVID-19 epidemic. They consider sets of admissible values for initial conditions, inputs, and parameters to enlarge the prediction performance. The results confirm that predicting the outbreak development with reasonable accuracy is possible by selecting different contact profiles between the countries’ compartments.

The fifth paper is entitled **“Monitoring and Forecasting the**

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COVID-19 Epidemic" by Peter C. Young and Fengwei Chen. The authors suggest two relatively simple data-based metrics that could be used in conjunction with the estimation of the reproductive number, R(t), and provide rapid indicators of how the epidemic is evolving. The new metrics are the epidemic rate of change and a related state-dependent response rate parameter, recursive estimates of which are obtained from dynamic harmonic and dynamic linear regression algorithms. The effectiveness of the approach is illustrated by the analysis of COVID-19 data in the UK and Italy.

The sixth article is entitled **"The Ockham's razor applied to COVID-19 model fitting French data"** by Mirko Fiacchini, and Mazen Alamir. The authors debate on the suitability of complex models for reproducing and forecasting the pandemic evolution since, although relevant from a mechanistic point of view, they could lead to non-identifiability issues. The paper shows that a two-dimensional model with only two parameters can reproduce the time series of daily demises caused by COVID-19 in the different French regions.

The seventh paper is authored by Alessandro Borri, Pasquale Palumbo, Federico Papa, and Corrado Possieri is entitled **"Optimal design of lock-down and reopening policies for early-stage epidemics through SIR-D models"**. Accounting for both health costs and economic costs, the authors propose optimal design policies, in terms of optimal timing of lock-down/release and optimal percentage of quarantined/released susceptible individuals. The technique is then applied in a realistic simulation scenario based on the data of the COVID-19 epidemic in Italy.

"Robust and optimal predictive control of the COVID-19 outbreak" is the eighth paper, authored by Johannes Köhler, Lukas Schwenkel, Anne Koch, Julian Berberich, Patricia Pauli, and Frank Allgöwer. To minimize the number of fatalities predicted over two years by a fitted model of the German COVID-19 outbreak, the authors investigate adaptive feedback policies based on model predictive control (MPC) to control the COVID-19 pandemic robustly and optimally via social distancing measures.

The ninth paper discusses testing, which is a critical issue during epidemics. The paper is entitled "**Smart Testing and Selective Quarantine for the Control of Epidemics"**, is authored by Matthias Pezzuto, Nicolas Bono Rossello, Luca Schenato, and Emanuele Garone and proposes a policy to smartly select the individuals to be tested. The infection probability for the different individuals is updated based on the stochastic model of the phenomenon and the information collected in the previous days. Better testing techniques are shown to be central to reduce the spread of the disease while limiting the number of confined individuals if compared with the simple contact tracing of positive individuals and to an off-line test selection strategy based on the number of contacts.

The tenth paper, authored by Michele Garetto, Emilio Leonardi, and Giovanni Luca Torrisi, is entitled "**A time-modulated Hawkes process to model the spread of COVID-19 and the impact of countermeasures"**. Based on a time-modulated Hawkes process, the article introduces a model that captures the impact of undetected asymptomatic and super-diffusive individuals and considers time-varying countermeasures and detection efforts. This approach allows a particularly faithful description of virus-specific features.

The guest editors are grateful to all the authors, for their important contributions, and to all the reviewers who evaluated the manuscripts submitted to the second special issue, for their valuable comments and suggestions that significantly improved the quality of the contributions.

Declaration of Competing Interest

The author(s) declare(s) that there is no conflict of interest.

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