Optimal control strategies on COVID-19 Symptom Data Challenge based on a fractional order age-structured generalized SEIR model

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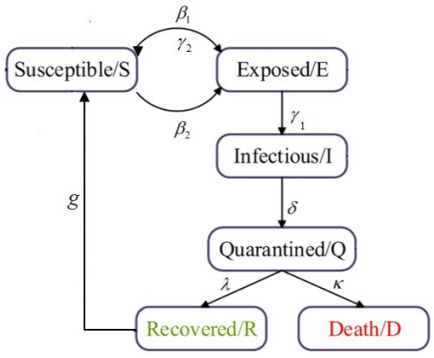
Abstract. Novel Coronavarious (COVID-19) has spread over the world, causing serious casualties and losses. In order to grasp and prevent the pandemic timely, a fractional order age-structured generalized SEIR (Fo-AGSEIR) epidemic model is proposed. Based on a variety of COVID-19 symptom data provided by Facebook and Google from March 5th,2020 to October 3rd, 2020, we reliably estimate key epidemic parameters and make predictions on the epidemiological trend and death cases for California. Using uncertain models, comparative analysis on the predicted trends under different mitigation and intervention scenarios, which are affected by the psychology effect factors and mobilities, are made. Moreover, we predict the effect of the vaccine fairness priority implementation of different age structures on COVID-19 epidemic trends. Numerical simulations using Simulink Design Optimization are given to support our analysis. In summary, the integration of symptom data based on the Fo-AGSEIR model enable the creation of models that identify inflection points in state COVID outbreaks with greater sensitivity, specificity, and timeliness compared to current indicators.

Introduction

The transmission of pneumonia associated with COVID-19 firstly reported in Wuhan, China is still a worldwide epidemic. By October 18th, 2020, according to the World Health Organization (WHO), there are 39,944,882 confirmed cases and 1,111,998 confirmed deaths spreading to 235 countries, areas or territories. With the development of globalization, traffic and environmental conditions foster the spread of the disease that, even in the absence of fatal forms, breed significant economic and social costs. During the epidemic prevention war, besides medical and biological research, theoretical researches based on statistical; mathematical modeling and optimal control problems also play important roles. Understanding and forecasting epidemic trends, integrating valid symptom data, considering vaccine fairness priority and determining effective mitigation and intervention to control the pandemic with an effective age-structured model are among the priorities of current research.

Actually, the infection rate of COVID-19 satisfies the power law. Considering the short-term rapid outbreak epidemic model, system dynamics has properties of inhomogeneity. Basic integer order epidemic models cannot describe epidemic characteristics or get ideal fitting and prediction of models. On the contrary, the long memory property of fractional order systems can deal with such infectious disease process. The compartment model can be drawn as a fractional order dynamic system. It is necessary to propose the fractional order age-structured generalized SEIR (Fo-ASGEIR) model in Figure. 1. Besides, the analysis, which reflect the likelihood of epidemic or suppression, of control strategies affected by mobility and psychology effect data on uncertain models are derived. *Simulink Design Optimization* is applied to fit the epidemic model. Combining the symptom data of different age groups, we analyze the infection trends caused by different vaccine fairness priority strategies under the age-structure model. In summary, it is Fo-AGSEIR model that better controls the epidemic trends, reduces deaths, affects mitigation and intervention policies.



(a) GSEIR Model

$$
\begin{cases}
{}_0^C D_t^{\alpha_f} S(t) = -\dfrac{\beta_1 I(t)}{N} S(t) - \dfrac{\beta_2 \mathrm{I}^{\alpha_e} E(t)}{N} S(t) + \gamma_2 E(t) + gR(t), \\
{}_0^C D_t^{\alpha_f} E(t) = \dfrac{\beta_1 I(t)}{N} S(t) + \dfrac{\beta_2 \mathrm{I}^{\alpha_e} E(t)}{N} S(t) - (\gamma_1 + \gamma_2) E(t), \\
{}_0^C D_t^{\alpha_f} I(t) = \gamma_1 E(t) - \delta I(t), \\
{}_0^C D_t^{\alpha_f} Q(t) = \delta I(t) - (\lambda + \kappa) Q(t), \\
{}_0^C D_t^{\alpha_f} R(t) = \lambda Q(t) - gR(t), \\
{}_0^C D_t^{\alpha_f} D(t) = \kappa Q(t).
\end{cases}
$$

(b) Epidemic system

Figure 1: fractional order age-structured generalized SEIR model.

References

[1] Angstmann C. N., Henry B. I, McGann A. V. (2016) A fractional-order infectivity SIR model. *J. Physica A: Statistical Mechanics and its Applications* 452: 86-93.

[2] COVID-19 ForecaseHub, website **https://covid19forecasthub.org/**

[3] COVID-19 Facebook Symptom Challenge, website **https://www.symptomchallenge.org/**

[4] COVID-19 case data from John Hopkins database, website **https://github.com/CSSEGISandData/COVID-19**.