Chapter 1
A Comprehensive Exploration of Mathematical Models and Machine Learning Techniques for COVID-19

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ABSTRACT

Mathematical modeling has proved to be useful in predicting the spread of infectious diseases and assessing the dynamical behavior of contagious diseases, including COVID-19. Various models aid in forecasting COVID-19 spread, such as SEIR (Susceptible – Exposed – Infected – Recovered), SIR (Susceptible – Infected – Recovered), SIRD (Susceptible – Infected – Recovered – Death), and SIRVD (Susceptible – Infected – Recovered – Vaccinated – Death). With recent technological advancements, forecasting of COVID-19 can also be done using machine learning techniques such as SVM (support vector machine), decision tree, random forest, and linear regression. This chapter delves into the various mathematical models and provides simulations using Python and machine learning techniques for COVID-19. These simulations provide essential insights into the spread of infectious diseases and evaluate which machine learning algorithm performs better using evaluation metrics.

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INTRODUCTION TO MATHEMATICAL MODELLING

Mathematical modelling is a crucial aspect of predicting the spread of infectious diseases. By the number of people infected, recovered, or passed away and the rate at which the disease will spread helps the creation of a mathematical model. This information is essential for policymakers and public health officials to make informed decisions about disease control and prevention, particularly during outbreaks such as COVID-19. Mathematical modelling has already proven its worth in predicting the impact of social distancing measures and vaccine efficacy. Its ability to predict potential outbreaks and guide early intervention is invaluable. As such, it is evident that mathematical modelling plays a vital role in disease forecasting and planning effective public health responses.

Mathematical Models for COVID-19

The first COVID-19 was detected in Wuhan, China, in December 2019. COVID-19 was later declared a Public Health Emergency by the World Health Organization (WHO) on 30th January 2020 and a global pandemic on 11th March 2020 (Hiscott et al., 2020). The Ministry of Health and Family Welfare (MoHFW), India, reported the active cases to be 66,170 as of 21st April 2023 (GoI, 2023) and 843 as of 27th March 2024. Various studies and research are carried out to control the spread of the virus and study its behavior, and one of the methods is mathematical modelling. Mathematical modelling uses mathematical equations and data to represent a real-world system or phenomenon, aiming to understand its behavior and make predictions (Madubueze et al., n.d.). It involves identifying relevant variables, formulating assumptions, selecting appropriate mathematical techniques, and validating the model with empirical data (Biggerstaff et al., 2022). The most commonly used mathematical models are the Susceptible - Exposed - Infective – Recovered (SEIR), Susceptible – Infected – Recovered (SIR), and Susceptible – Infected – Recovered – Deceased (SIRD) models. The SEIR model specifies how susceptible individuals become exposed to the virus, become infectious and then recover, whereas the SIR model does not include the exposed (E) population.

Some epidemiological mathematical models commonly used are:

- Susceptible – Infectious (SI), which applies to HIV/AIDs which is the basic model
- Susceptible – Infectious – Recovered (SIR) is applied to measles, mumps, and rubella
- Susceptible – Infectious – Susceptible (SIS), which is applied to the common cold (Chitnis, 2017).

To show that people migrate from the susceptible class S to the infective class I and infective class I to the removed class R, the SIR explains an illness that gives immunity against reinfection. These kinds of diseases frequently cause epidemics. Viruses typically cause SIR-type diseases, whereas bacteria mainly cause SIS-type diseases (Brauer & Castillo-Chavez, n.d.). In the last three years, much research has been conducted to study and understand the dynamics of COVID-19. In research conducted by Eppes (Jones et al., 2021), the author used the SEIR model to analyze the spread of the virus in Hampton Roads, Virginia, with the added parameter 'σ' representing the rate of social interaction in a population, concluding that social distancing was the key to reducing the infection. (Akuka et al., 2022) researched mathematical analysis of the COVID-19 transmission dynamics model of Ghana to study the impact of quarantine and double-dose vaccination with added parameters such as V_1 (first dose of vaccine), V_2