Computational Simulation of COVID-19 Transmission Dynamics

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ABSTRACT

The COVID-19 pandemic highlighted the importance of mathematical modeling in understanding and predicting disease spread. This study implements the Susceptible-Infected-Recovered (SIR) model to simulate the transmission dynamics of COVID-19. The model is numerically solved using the Runge-Kutta method and visualized through a time-dependent simulation. Results demonstrate the progression of the pandemic, emphasizing the peak infection period and the eventual stabilization of the recovered population. Computational simulations such as this provide insights into epidemic control strategies.

Introduction

Epidemiological models have played a crucial role in understanding infectious disease dynamics, particularly during the COVID-19 pandemic. The Susceptible-Infected-Recovered (SIR) model is a fundamental compartmental model that describes the transmission of infectious diseases within a population. By representing individuals as susceptible (S), infected (I), or recovered (R), the model provides insight into the spread and control of epidemics. This study implements a numerical simulation of the SIR model to analyze the progression of COVID-19 over time.

Results

The numerical solution of the SIR model was obtained using Python's SciPy library, employing the `odeint` function to integrate the system of differential equations. The initial conditions assume a population of 1000 individuals, with one infected case at the start of the simulation. The model parameters include a transmission rate $\beta = 0.3$ and a recovery rate $\gamma = 0.1$.

As shown in Figure 1, the susceptible population declines as the infection spreads. The number of infected individuals rises to a peak before gradually decreasing, while the recovered population steadily increases. Eventually, the system stabilizes with a majority of the population in the recovered compartment.

Discussion

The simulation results illustrate the dynamics of a COVID-19 outbreak under the given parameters. The peak infection period highlights the strain on healthcare systems, emphasizing the importance of interventions such as social distancing and vaccination. While the SIR model provides a basic framework, more complex models incorporating factors like asymptomatic carriers, reinfection, and external interventions can enhance accuracy in real-world applications.

Methods

The SIR model is governed by the following set of differential equations:

$$\frac{dS}{dt} = -\beta SI \tag{1}$$

$$\frac{dI}{dt} = \beta SI - \gamma I \tag{2}$$

$$\frac{dR}{dt} = \gamma I \tag{3}$$

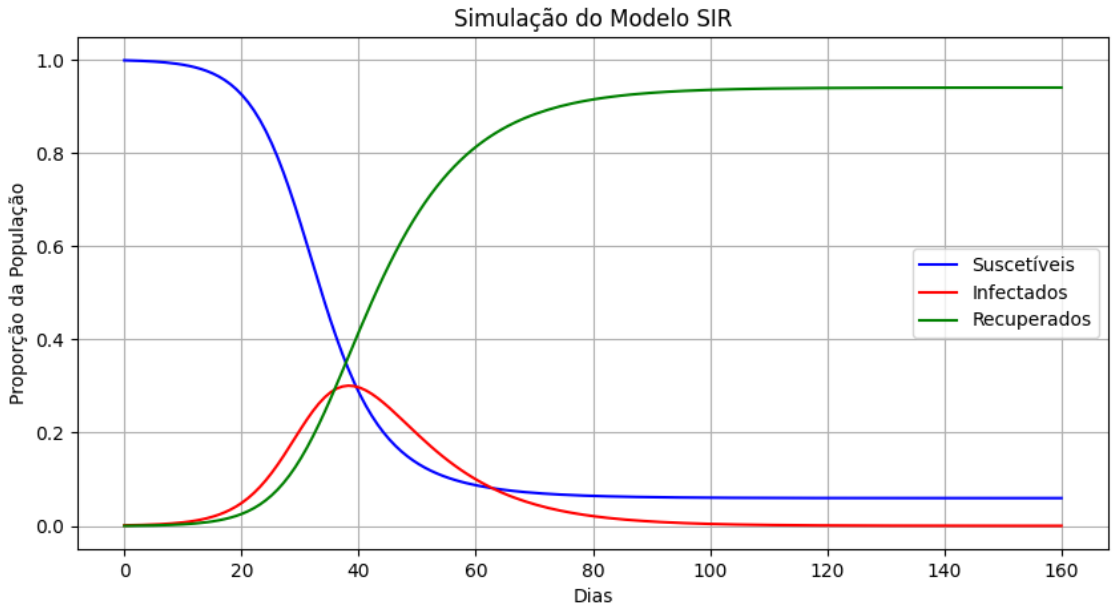

Figure 1. SIR model simulation results. The blue curve represents the susceptible population, the red curve represents the infected individuals, and the green curve represents recovered individuals over 160 days.

where β is the transmission rate, and γ is the recovery rate. The numerical solution was implemented in Python, solving the system using the Runge-Kutta method via `odeint`. The simulation was run for 160 days, and results were plotted using Matplotlib.

References

1. Quintana, S. A., Espinoza, R., Rojas, J., & Gabaglio, S. *Dinámica y simulación computacional del COVID-19 en Paraguay en el mes de febrero del 2021*. Medical Sciences Journal, 26(4), e2501 (2021).