Computational Modeling of the COVID-19 Disease

Numerical ODE Analysis with R Programming

This book presents a computer-based model for the dynamics of the COVID-19 epidemic that developed in late 2019. The model is an extension of the basic SIR (Susceptibles Infecteds Recovered) model and consists of five ordinary differential equations (ODEs) with the dependent variables: (1) susceptibles, (2) asymptomatic infecteds, (3) symptomatic infecteds, (4) recovereds, (5) deaths.

The time scale is 52 weeks starting from the beginning of the COVID-19 disease, and the evolution of the five dependent variables is computed by the numerical integration of the five initial value ODEs from an initial condition (IC) of (1) the susceptibles taken as the population for a country, (2) small values for the infecteds, and (3) zero values for the recovereds and deaths.

The numerical integration of the 5 ODE (five equations in five unknowns) model is performed with routines coded (programmed) in R, a quality, open-source scientific computing system that is readily available from the Internet. Formal mathematics is minimized, e.g., no theorems and proofs. Rather, the presentation is through detailed examples that the reader/researcher/analyst can execute on modest computers. The five ODE dependent variables are plotted against t with basic R plotting utilities.

Chapter 1 is an introduction to the 5 ODE model with a detailed discussion of the associated R code. Chapter 2 presents a methodology for the computation and display of the ODE RHS terms and LHS derivatives in t. These terms explain the properties of the ODE solutions. Chapters 3,4 present variations of the basic ODE model, for example, (1) limitations on the rate of conversion of susceptibles to infecteds and (2) reductions in the rate of COVID-19 transmission resulting from a postulated vaccine or therapeutic drug. Chapter 5 concludes with a discussion of the ODEs that include selected rates delayed in time to reflect the incubation period of the asymptomatic infecteds.

The routines are available from a download link so that the example models can be executed without having to first study numerical methods and computer coding. The routines can then be applied to variations and extensions of the ODE model, such as changes in the parameters and the form of the model equations.

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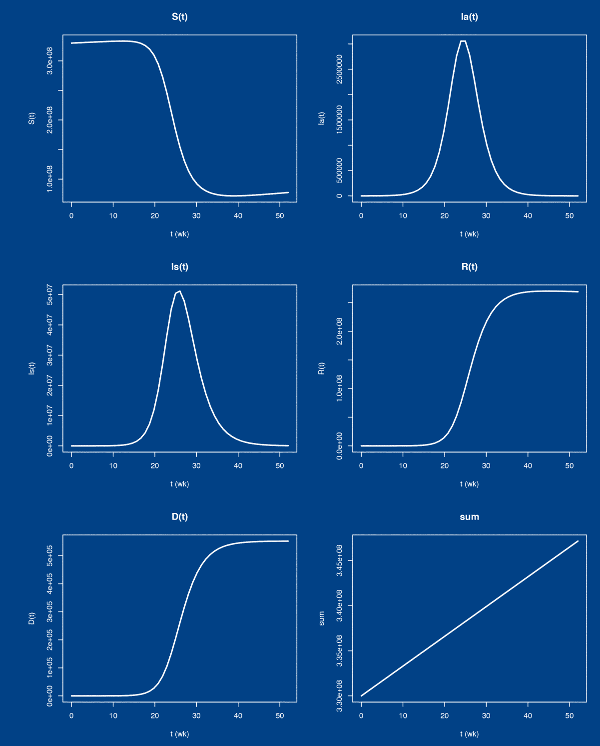

$$\frac{dS}{dt} = r_p - r_{SI_a} S I_a - r_{SI_s} S I_s + r_R R$$

$$S(t=0) = S_0$$

William E Schiesser

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