Proceedings of the 2022 Winter Simulation Conference
B. Feng, G. Pedrielli, Y. Peng, S. Shashaani, E. Song, C.G. Corlu, L.H. Lee, E.P.Chew, T.Roeder, and P. Lendermann, eds.

ANALYSIS OF COVID-19 USING A MODIFIED SEIR MODEL TO UNDERSTAND THE CASES REGISTERED IN SINGAPORE, SPAIN, AND VENEZUELA

Raúl Isea

Fundación IDEA
Hoyo de la Puerta
Baruta, 1015, VENEZUELA

Rafael Mayo-García

CIEMAT
Avda. Complutense,40
Madrid, 28040, SPAIN

ABSTRACT

This work proposes a modification of a compartmental-type model based on the Susceptible-Exposed-Infected-Recovered (SEIR) scheme to describe the dynamics of contagion by Covid-19. As an example, the different incidents that occurred in Singapore, Spain, and Venezuela have been analyzed to demonstrate the usefulness of the methodology developed in this work, which can be extended to other countries.

1. METHODOLOGY

Thanks to the daily records of COVID-19 contagions, such as those from the Johns Hopkins Coronavirus Resource Center (https://coronavirus.jhu.edu/), public policies have been designed to contain this disease with the imposition of quarantines, social distancing measures, or the mandatory use of masks, among other measures (examples of these measures can be found in Al-arydah *et al*. 2021). Despite this, outbreaks have emerged in many countries, it has not been possible to contain this pandemic. As an example, we can cite the recent incidents in the city of Guangzhou, where restriction measures have been imposed again to stop the current outbreak, such as the closure of the city without allowing the landing of commercial flights.

In this work, a variant of the Susceptible-Exposed-Infected-Recovered (SEIR) type model has been developed and implemented to explain the spread of Covid-19. With this model, it has been possible to describe the contagion dynamics of this disease from the daily registry of infected cases, so that it would be possible to predict the number of infected people per country in the short term. The scheme of this mathematical model used in this work can be represented by a 4-ODE system:

$$\frac{dS(t)}{dt} = \Lambda_P - \frac{(\beta_P E(t)+d)S(t)}{N} - \mu S(t) \quad ; \quad \frac{dE(t)}{dt} = \frac{\beta_P E(t)S(t)}{N} - (w_P + \mu)E(t)$$

$$\frac{dI(t)}{dt} = m_P E(t) - (\eta + \mu)I(t) \quad ; \quad \frac{dR(t)}{dt} = \kappa_P E(t) + \eta I(t) - \mu R(t)$$

The procedure for resolving this system is to determine the equilibrium conditions based on the calculation of the critical or equilibrium points (Isea 2018). When this is achieved, the next step is to calculate the expressions of the eigenvalues to determine the equilibrium conditions of the system for each critical point. By doing so, it is possible to determine the conditions upon which the system will be in equilibrium taking into account the fitting of the parameters derived from the daily record of contagions. The calculation by a least squares method to determine the value of the parameters used in the model has been described by a defined function that is minimized. This corresponds to the differences in the expressions of the values obtained from the function that is adjusted with respect to the observed values, which in this case are the daily record of the Covid-19 cases. To do this, a program implemented in Python was designed to minimize the expression of χ using scipy libraries (Virtanen *et al*. 2020).

In addition, a sensitivity analysis was also performed in order to examine how the dependence of the parameters is after performing the least squares fitting. From this procedure, it is possible to detect which parameters are the most sensible ones by using an analysis based on the Morris Screening method.

2. RESULTS

Table 1 shows the different values of the parameters obtained from the ODE system for Singapore, Spain, and Venezuela according to the records of Johns Hopkins University. It is important to indicate that the final value obtained from the least squares fitting was 99.94%, 97.89%, and 84.41% for Singapore, Spain, and Venezuela, respectively.

Table 1: Values obtained in the ODE system for the targeted countries. β_p is the contagion rate, Λp is the per-capita birth rate, m_p is the infection rate obtained from the group of exposed people, η is the rate of change of the infected people, d is a global parameter on its own that considers the change in the contagion rate of each country, and w_p is an infection rate.

Country	**Population**	β_P	Λ_P	m_P	**η**	**d**	w_P
Singapore	5,453,600	2.0754	0.7172	1.5481	0.0465	0.5611	2.4815
Spain	46,745,211	1.8036	0.8372	1.2068	0.0382	0.6212	2.2770
Venezuela	28,704,947	1.5292	0.6791	1.5556	0.4342	1.1810	0.8440

As an example, additional results obtained for Singapore for the least square method applied to the contagion rate as days go by are depicted in Figure 1.

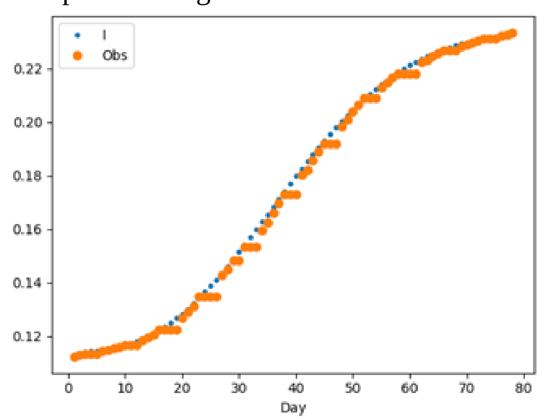

Figure 1: Evolution of the contagion rate in Singapore (green dots: calculated; orange dots: observed).

Additional results about the numerical determination of the equilibrium points according to the Covid-19 cases in the targeted countries (eigenvalues included) and the sensitivity analysis of the model presented describing the susceptible, exposed, and infected population will be included in the poster.

REFERENCES

Al-arydah, M., H. Berhe, K. Dib, and K. Madhu. 2021. "Mathematical modeling of the spread of the coronavirus under strict social restrictions". *Math. Methods Appl. Sci.* doi: 10.1002/mma.7965, online ahead of print.

Isea, R. 2018 "Analytical solutions for the initial steps of the intracellular dynamics of influenza a virus". *Acta Scientific Microbiology* 1(6):6.

Virtanen, P*et al*. 2020. "SciPy 1.0 Contributors. SciPy 1.0: fundamental algorithms for scientific computing in Python". *Nat Methods* 17(3):261-272.