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Estimating Active Cases of Infectious Disease Using Seird Model: Case of Covid-19 Diseases in Malaysia

Azrul Azim Mohd Yunus[1,2,*], Shahrina Ismail[1], Arif Asraf Mohd Yunus[1], Muhammad Safwan Ibrahim[1], Shaharudin Ismail[3]

[1] Department of Financial Mathematics, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Bandar Baru Nilai, 71800, Negeri Sembilan, Malaysia
[2] Risk and Analytics Research Group, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Bandar Baru Nilai, 71800, Negeri Sembilan, Malaysia
[3] Department of Information Security and Assurance, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Bandar Baru Nilai, 71800, Negeri Sembilan, Malaysia

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ABSTRACT

The global outbreak of the novel coronavirus disease (COVID-19) has unleashed widespread turmoil. The number of confirmed cases continues to rise, and numerous countries exhibit a persistent upward trajectory in daily infections. In an effort to predict the trajectory of active cases, we employed the SEIRD mathematical model, which provides a visual representation of the ongoing spread of COVID-19. SEIRD models were used to estimate and visualize the trend of active cases, recovery, and death during the infection period. Using the *lmfit* package in Python, the solution for Non-Linear Least-Square Minimization was provided and minimalizes the error for the curve-fitting, thus giving the optimal number for the coefficient for infection, recovery rate, and death rate. It is important to estimate the current trend of an active case in Malaysia as early action can minimize the effect of COVID-19 infections.

1. Introduction

In December 2019, a new variant of Coronavirus, known as SARS-CoV-2, emerged in Wuhan, Hubei Province, China, leading to the development of a severe respiratory syndrome named COVID-19. Subsequently, the World Health Organization (WHO) declared the outbreak a global pandemic on March 11th, and it has since rapidly disseminated across the globe.

Currently, the globe is grappling with an unparalleled crisis posed by the COVID-19 pandemic, triggered by a novel coronavirus known as Sars-CoV-2. This virus, believed to have originated from bats, was transmitted to humans in Wuhan, China, around December 2019. The situation presents an extraordinary global challenge with widespread implications. There are still active COVID-19 cases reported around the globe. Recently, Malaysia has observed an increment in active COVID-19 cases,

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[*] *Corresponding author.*
E-mail address: azrulazim@usim.edu.my

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as shown in Figure 1. Although the admission for ICU cases is still manageable [1], the government has already taken precautions and advised people to start taking appropriate action, like wearing face masks in crowded spaces and using hand sanitizer [2].

Amid the COVID-19 pandemic, a crucial element in formulating effective preventive measures to mitigate the impact of the virus spread is the utilization of mathematical models. These models play a pivotal role in forecasting potential scenarios, allowing government and health authorities, such as the Ministry of Health (MOH), to implement timely and appropriate actions. These actions may include the enforcement of measures like lockdowns, movement control orders (MCOs), social distancing protocols, and the mandatory use of masks and hand sanitizers in public spaces [3]. Furthermore, the insights derived from the mathematical model results enable the government to proactively plan and respond to emerging situations. This proactive approach is particularly vital to prevent the overwhelming of hospital beds, especially in Intensive Care Units, as a consequence of a surge in COVID-19 cases. By anticipating the potential strain on healthcare resources, authorities can better allocate and manage medical facilities to address the needs of patients requiring intensive care [4].

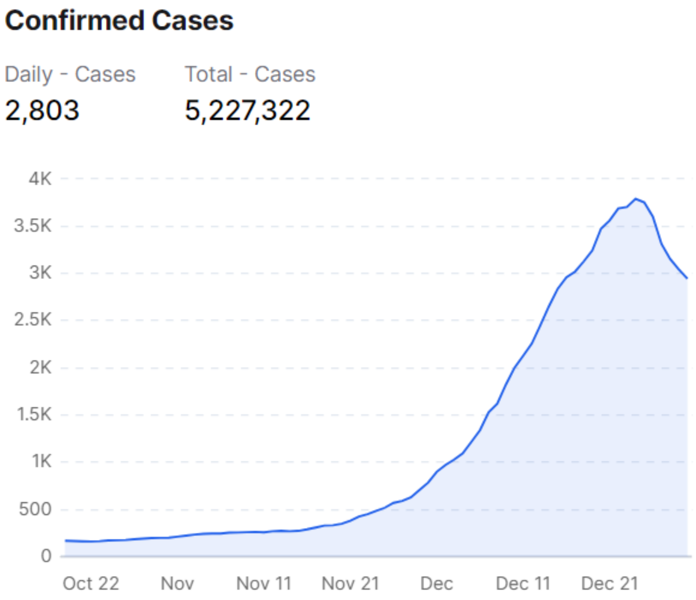

Fig. 1. Graph of confirmed daily reported cases from 22 Oct 2023 till 31 Dec 2023 (retrieved from https://data.moh.gov.my/dashboard/covid-19)

1.1 Compartment Model

Mathematical modeling serves as a crucial tool for transforming real-world problems into mathematical equations, offering a comprehensive perspective, solutions, and predictions. Researchers employ this approach to formulate mathematical equations that unveil the inherent nature of a problem and proactively devise solutions to avert potential disasters [5]. In the context of infectious diseases, mathematical models play a vital role in projecting the potential outcomes of a pandemic, thereby providing valuable insights for public health interventions [6]. By incorporating simple assumptions, statistical data, and mathematical principles, these models can ascertain parameters for various infectious diseases, enabling the assessment of the effectiveness of different interventions [7]. The modeling process facilitates the identification of interventions to implement for prevention, as well as those to test or predict potential development trends [8]. Overall, mathematical modeling has become an indispensable tool in the realm of public health, aiding in strategic decision-making and proactive measures against emerging threats. The most basic compartmental model is the SIR model [9], which is shown in the figure below and is described by the following set of Eq. (1):

$$\begin{aligned} \frac{dS}{dt} &= -\beta \frac{S}{N} I, \\ \frac{dI}{dt} &= \beta \frac{S}{N} I - \gamma I, \\ \frac{dR}{dt} &= \gamma I. \end{aligned} \tag{1}$$

Within compartmental models, the overall population N is segmented into distinct compartments, as denoted by Eq. (1). The specific structure and connectivity of these compartments vary based on the intricacies of the model under examination [10]. One can conceptualize these compartments as nodes within a graph. Each connecting edge is associated with transmission coefficients that dictate the efficacy of that edge in influencing the population dynamics of the interconnected compartments. Table 1 shows some of the notations used in the compartment model; meanwhile, Figure 2 shows the dynamics of several compartment models.

Table 1
Notations for the compartment model

Notation	Description
S,E,I,R,D	Name of the compartment
S,E,I,R,D	Population in the compartment
$\alpha, \beta, \gamma, \mu, \lambda$	Coefficient for compartment model
R_0	Reproductive number

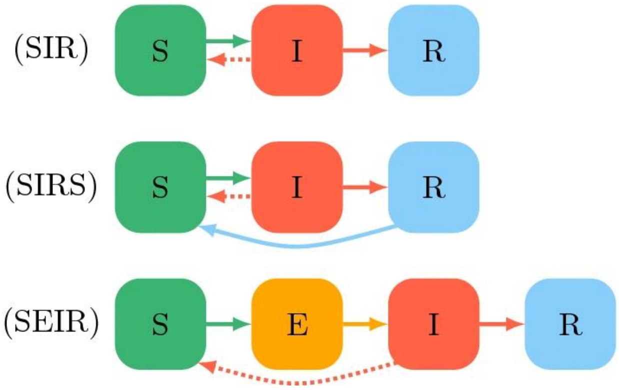

Fig. 2. Dynamics of compartment model [11]

Here, beta and gamma, referred to as transmission coefficients denoting the contact rate and incubation period, respectively, play pivotal roles in disease transmission [12]. Concurrently, the reciprocal of beta (1/beta) and gamma (1/gamma) serve as indicators for the mean duration of infectiousness and the average period of infectivity. While there is typically a time delay between infection acquisition and the onset of infectivity, the SIR model simplifies this dynamic by assuming that individuals become infectious immediately upon contracting the infection. This simplification disregards any inherent delay in the manifestation of infectiousness following exposure [10].

1.2 SEIRD Model

SEIRD is one example of a compartment model. It is given by the differential equation system given below [13] as in Eq. (2):

$$
\begin{aligned}
\frac{dS}{dt} &= -\frac{\beta SI}{N}, \\
\frac{dE}{dt} &= \frac{\beta SI}{N} - \sigma E, \\
\frac{dI}{dt} &= \sigma E - \gamma I - \mu I, \\
\frac{dR}{dt} &= \gamma I, \\
\frac{dD}{dt} &= \mu I,
\end{aligned}
\tag{2}
$$

where, $N = S + E + I + R + D$. From the model, the assumption involves the number of susceptible persons, *S,* that will reduce by the rate of β. The number of infected persons increases at the rate of β and decreases at the rate of σ. The number of infected persons increases at the rate of σ but at the same time reduces at the rate of γ and μ. The number of recovered persons is increased by λ and at the same time, the number of death due to COVID-19 are given by the rate of μ. Figure 3 summarises the dynamic of SEIRD models [14].

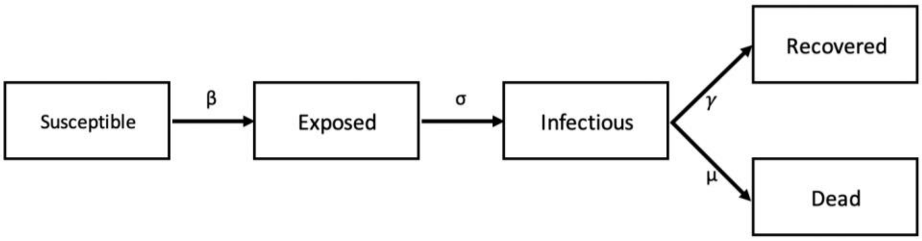

Fig. 3. Dynamics of SEIRD model

2. Parameter Optimization and Data Simulation

2.1 Setting the Parameter

Data were obtained from the official MOH Malaysia covidnow GitHub (https://github.com/MoH-Malaysia/covid19-public). Considering there are 54733 initial active cases, 3232 initial recovered patients, and 13 initial deaths reported, this data is considered as initial data at $t = 0$. From there the first 25 days of actual data from MOH comprising numbers of active cases, recovered and death, were used as training data for our parameter optimization. Using *lmfit* package in Python for parameters optimization [15], the following results were obtained and summarized in Table 2.

Table 2
Parameter optimization for constant coefficient in SEIRD

Name	Value
beta	0.24985083
sigma	0.08102712
gamma	0.06047762
mu	1.43e-04

Here, beta, sigma, gamma, and mu represent the exposed rate, infection rate, recovery rate, and death rate, respectively. Figure 4 shows the predicted number of infection cases, recovery cases and death cases for COVID-19 infections from t = 0 till t = 25 days. The comparison between the predicted and the actual data was presented in Figures 5, 6, and 7. Figure 5 shows the comparisons between forecast (straight line) and real-time observed data (dotted) for active infected cases. It shows that our forecast can predict the increase in active case trends.

Fig. 4. Graph for projected infected, recovered and death of COVID-19 cases from *t* = 0

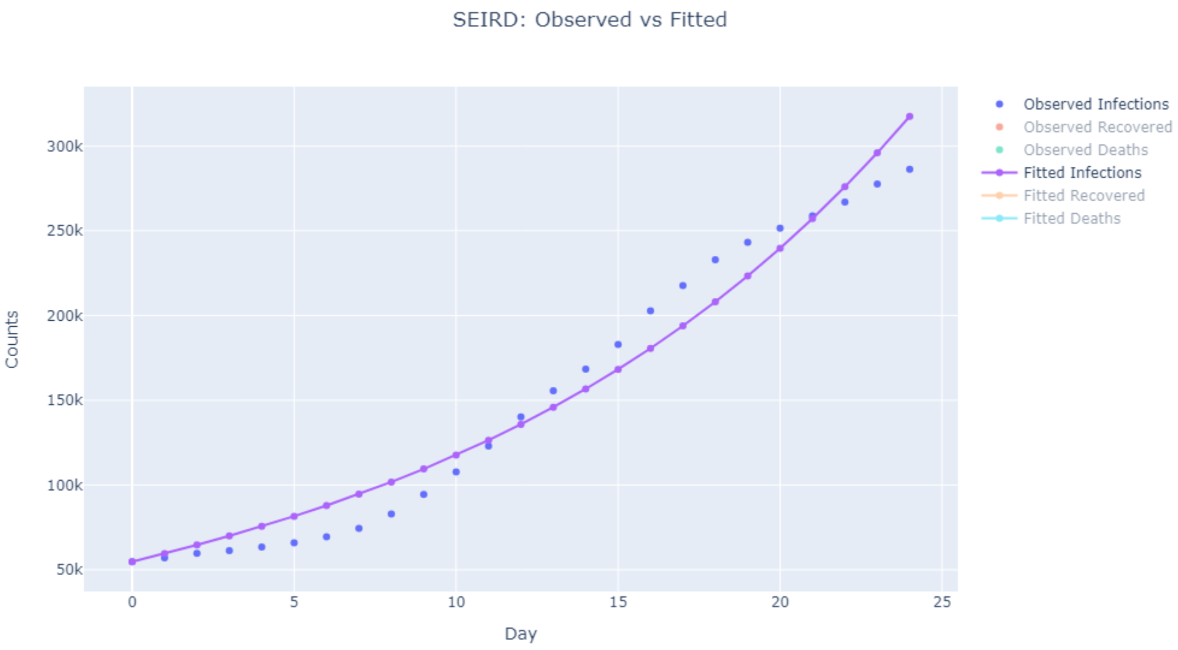

Fig. 5. Comparisons for observed infected cases and predicted infection cases

Figure 6 shows the comparison of forecast number for recovered case (straight line), and actual recovered case (dotted) as reported by MOH. It shows that the results can forecast the number of recovered patients over time. On the other hand, Figure 7 shows the comparison of forecast number for death case (straight line), and actual death case (dotted) as reported by MOH. This forecast is important as it can help prepare the government for planning for action to prepare in pandemic management (source).

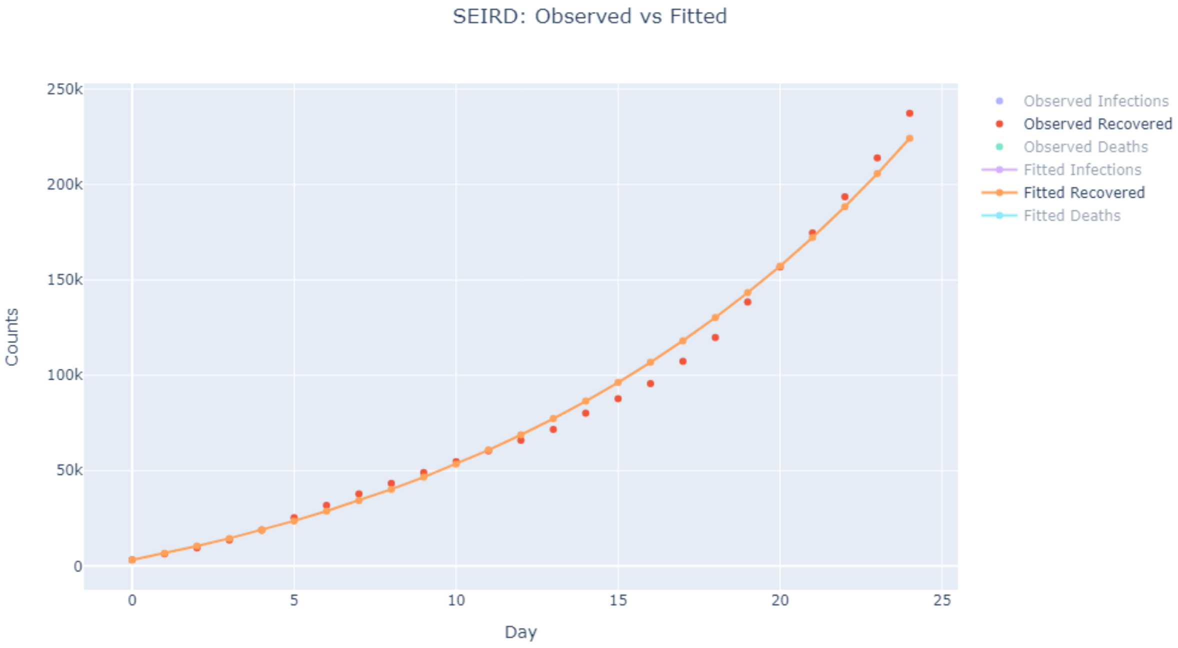

Fig. 6. Comparisons for observed recovered case and predicted recovered cases

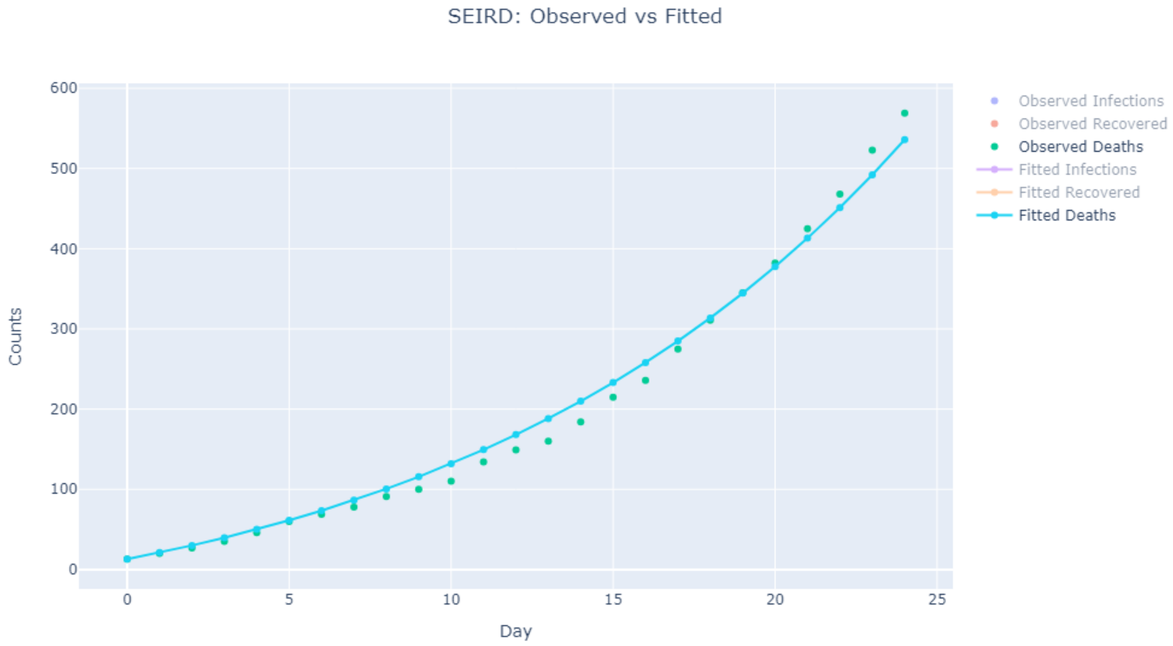

Fig. 7. Comparisons for observed death case and predicted death cases

3. Discussions

3.1 Issues on SEIRD Models

The initial value for this simulation depends on one assumption. There might be errors due to how the data was interpreted. There are other factors that might affect the modelling and parameter optimization. One of the factors that might contribute to this error might be due to how the data was reported or the number of cases obtained by the government. The backlog of the number of deaths reported also plays a role in the difference in the number of deaths reported. Other factors that might contribute to error are the number of unreported cases. Unreported cases could provide lower predicted cases, while virus spread could be more severe than predicted [16]. The way certain governments reported the number of cases also could provide errors in the estimation of the number of deaths [17]. Due to these factors, researchers combine the number of deaths cases together with recovered cases [18,19]. This model is also known as SEIR (Susceptible, Exposed, Infected, and Removed). This could prevent the large coefficient error, thus providing a better estimation for the reported number of cases.

4. Conclusions

In this work, we apply the SEIRD model to the Malaysian COVID-19 example and demonstrate that it can be used to estimate the number of active cases accurately. The SEIRD model is a flexible tool that can be used to study more infectious diseases. It is vital to note, however, that the accuracy of the model relies on the quality of the data that is used to parameterize it. In addition, the model does not account for all the variables, including human behaviour and the virus mutation (such as gamma, delta, omicron, etc) that may affect the transmission of an infectious disease. For the future, one can integrate the vaccination rate and re-infection as part of the compartment model, namely SEIRS (Susceptible – Exposed – Infected – Removed), by considering the possibilities of one might get reinfected [20] and SVEIR (Susceptible – vaccinated – Exposed – Infected – Removed) where vaccination rate can help reduce the number of infections [21]. However, adding several new compartments in the model can cause the complexity of the solutions [22]. As for people, COVID-19 have changed the way people interact with others. Action likes wearing face mask, using hand sanitizer and self quarantine when infected with the virus. Besides, with the advancement of information technology i.e interactive class and also adoption in AI technology [23,24] already become new norm for teaching and learning session during pandemic .

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