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FORECAST ON COVID-19 CASES IN MALAYSIA USING SIRS MODEL AND ADAMS PREDICTOR-CORRECTOR METHOD

(Ramalan Kes COVID-19 di Malaysia dengan Menggunakan Model SIRS dan Kaedah Peramal-Pembetul Adams)

NUR RUSYIDAH AZRI, SARATHA SATHASIVAM*, CHEAH JUN NAM & TAN YI HANG

ABSTRACT

A new severe acute respiratory syndrome coronavirus 2 had become a significant threat to public health by 2020. The pandemic began in a city named Wuhan in China. It then spread throughout the rest of the world, including Malaysia. COVID-19 virus can spread between people in close contact because it spreads through droplets in the air. The virus can spread in small liquid particles from an infected person's mouth or nose when they cough, sneeze, speak, sing, or breathe. To reduce the number of cases in the nation, the Malaysian government created a new order named Movement Control Order (MCO). This paper presents a SIRS model to forecast the COVID-19 cases 100 days after the MCO held in Malaysia. MCO's impact was thought to have the potential to reduce COVID-19 cases. The model then generated a system of differential equations for the calculation proposed. 4-Step Adams-Bashforth-Moulton Predictor-Corrector method is used to predict the early COVID-19 outbreak in Malaysia. The number of corrector steps will be determined by the tolerance value. Then, the result from the numerical model using various step sizes is compared with the actual data. The outcome of a computer simulation in which the computation and graphing were done using MATLAB. The numerical method's performance in performing the early COVID-19 outbreak in Malaysia is discussed in terms of mean absolute percentage error (MAPE) and standard deviation absolute percentage error. The simulation results indicate that the computation should only use two corrector steps to optimize the forecast and computational time, regardless of the value of step size.

Keywords: COVID-19; Malaysia; SIRS model; predictor-corrector

ABSTRAK

Pada tahun 2020, novel sindrom pernafasan akut teruk coronavirus 2 telah menjadi ancaman utama kepada kesihatan awam. Pandemik bermula di Wuhan, China. Kemudian ia merebak ke seluruh dunia termasuk Malaysia. Virus COVID-19 boleh merebak antara kenalan rapat kerana ia merebak melalui titisan bawaan udara. Virus ini merebak sebagai zarah cecair kecil dari mulut atau hidung orang yang dijangkiti apabila orang yang dijangkiti batuk, bersin, bercakap, menyanyi, atau bernafas. Dalam usaha mengurangkan jumlah kes di negara ini, kerajaan Malaysia telah melaksanakan perintah baharu iaitu Perintah Kawalan Pergerakan (PKP). Kertas kerja ini membentangkan model SIRS untuk meramalkan kes COVID-19 100 hari selepas PKP di Malaysia. Model tersebut menjana sistem persamaan pembezaan biasa untuk pengiraan. Kaedah peramal-pembetul Adams-Bashforth-Moulton 4-langkah digunakan untuk meramal wabak awal COVID-19 di Malaysia. Bilangan langkah pembetulan ditentukan oleh nilai toleransi. Kemudian, hasil model berangka menggunakan pelbagai saiz langkah dibandingkan dengan data sebenar. Simulasi komputer dijalankan dengan menggunakan MATLAB untuk tujuan pengiraan dan graf. Prestasi kaedah berangka semasa wabak pertama COVID-19 di Malaysia dibincangkan dari segi min peratusan ralat mutlak dan sisihan piawai peratusan ralat mutlak. Keputusan simulasi menunjukkan bahawa pengiraan hanya perlu menggunakan dua langkah pembetul untuk mengoptimumkan ramalan dan masa pengiraan, tanpa mengira nilai saiz langkah.

Kata kunci: COVID-19; Malaysia; model SIRS; peramal-pembetul

1. Introduction

The novel coronavirus disease (COVID-19) spread throughout Asia by the end of 2019 and has become a global pandemic. COVID-19 is caused by a severe acute respiratory syndrome coronavirus 2 infections denoted as SARS-CoV-2 (Elezkurtaj *et al.* 2021; Lai *et al.* 2020). COVID-19 was discovered in Wuhan, China (Du *et al.* 2020), and was reported to the World Health Organization (WHO) in December 2019 (Sohrabi *et al.* 2020). The WHO then declared the COVID-19 outbreak a global health emergency in January 2020 (Abebe *et al.* 2020). Although some SARS-CoV-2 infections are asymptomatic, most cases result in mild to moderate illness with flu-like symptoms like sore throat, coughing, and fever (Ali & Alharbi 2020). A significant proportion of COVID-19 patients develop critical illness and require intensive care, such as extracorporeal oxygenation or mechanical ventilation (Supady *et al.* 2021), which can be fatal. Scientists have debated the origin of the SARS-CoV-2 because some believe the novel coronavirus was created in a laboratory (World Health Organization 2020). However, genetic evidence contradicts this hypothesis, indicating that SARS-CoV-2 did not evolve from a previously known virus backbone (Ciotti *et al.* 2020).

In Malaysia, it began to spread rapidly in early 2020 (Hasanat *et al.* 2020). The first case in Malaysia was discovered on 25th January 2020 and was traced back to three Chinese nationals who had previously had close contact with an infected person in Singapore (Khalid 2021; Elengoe 2020). After the news spread, the Ministry of Health Malaysia (MOH) quickly developed standard guidelines for COVID-19 management and established 34 hospitals and screening centers in each Malaysian state (Chan *et al.* 2019). According to information provided by the MOH, there were 673 COVID-19 cases in Malaysia on 17th March 2020 with a significant increase beginning on 15th March 2020 (Tang 2020). The first death of a COVID-19 patient in Malaysia occurred on 17th March 2020, with two deaths (Khoo *et al.* 2020).

The Malaysian government has been urged to keep an eye on the COVID-19 cases due to their critical rise. In order to prevent the disease from spreading by outlawing gatherings, outdoor activities, and travel, the Malaysian government implemented the Movement Control Order (MCO) on the 18th of March 2020 (Karim *et al.* 2020). The orders have been called 'lockdowns' in local and international media. To combat the spread of COVID-19 disease, MCO imposed restrictions on movement, international travel, and assembly, as well as mandated the closure of the industry, business, and educational institutions (Kamaludin *et al.* 2020; Musa *et al.* 2021). The stage of MCO in 2020 can be divided into 5 phases (The Star 2020),

First phase	: 18 Mar - 31 Mar
Second phase	: 1 Apr - 14 Apr
Third phase	: 15 Apr - 12 May
Conditional MCO	: 13 May - 9 Jun
Recovery MCO	: 10 Jun - 31 Aug

Official data on the COVID-19 epidemic in Malaysia is being gathered from an open-source website powered by the Crisis Preparedness and Response Centre (CPRC) Hospital System, National Public Health Laboratory, and MySejahtera in order to investigate disease transmission in the country. Table 1 shows the tabulated COVID-19 data in Malaysia for the number of cases per day, cumulative cases, number of recovered patients, number of active cases, number of deaths per day, and cumulative of death patients. Even though the number continues to rise for the first few days following the MCO, it begins to fall on the 15th April 2020, four weeks later. The new order's effectiveness will take longer than the 14 days specified for the first MCO (Ismail *et al.* 2021), so the government will continue to add days to the restriction. Strict Standard Operating Procedures (SOP) such as wearing masks, restricting outdoor activities, banning massive gatherings, and borders closure (Ganasegeran *et al.* 2020) have effectively cut down the infected population in our country (Yong & Sia 2021). By taking such measures in a country, the number of infected cases of infectious diseases can be reduced effectively. However, this may not work well for long-term benefits due to its negative impact on the economy of the country (Tajudin *et al.* 2021).

Table 1: Official data on the COVID-19 epidemic in Malaysia. Source: https://github.com/MoH-Malaysia/covid19-public

Date	New cases	Total cases	Recovered	Active cases	New death
17/03/2020	120	673	7	622	2
18/03/2020	117	790	11	728	0
19/03/2020	110	900	15	823	0
20/03/2020	130	1030	12	940	1
21/03/2020	153	1183	27	1062	4
22/03/2020	123	1306	25	1156	4
23/03/2020	212	1518	20	1343	5
24/03/2020	106	1624	24	1432	2
25/03/2020	172	1796	16	1576	3
26/03/2020	235	2031	16	1790	5
27/03/2020	130	2161	44	1874	2
28/03/2020	159	2320	61	1966	6
29/03/2020	150	2470	68	2043	5
30/03/2020	156	2626	90	2105	4
31/03/2020	140	2766	58	2182	5
01/04/2020	142	2908	108	2214	2
02/04/2020	208	3116	122	2298	2
03/04/2020	217	3333	60	2450	5
04/04/2020	150	3483	88	2509	3
05/04/2020	179	3662	90	2596	2
06/04/2020	131	3793	236	2489	2
07/04/2020	170	3963	80	2578	1
08/04/2020	156	4119	166	2567	1
09/04/2020	109	4228	121	2553	2
10/04/2020	118	4346	222	2446	3
11/04/2020	184	4530	165	2462	3
12/04/2020	153	4683	113	2497	5
13/04/2020	134	4817	168	2462	1
14/04/2020	170	4987	202	2427	3
15/04/2020	85	5072	169	2341	2
16/04/2020	110	5182	119	2330	2
17/04/2020	69	5251	201	2197	1

After a few months under the new order, COVID-19 cases have decreased in Malaysia (Aziz *et al.* 2020). Thus, it is intriguing to simulate the spread of COVID-19 in order to stop the virus in Malaysia from spreading. Mathematical modelling has become a vital tool for understanding the dynamics of infectious diseases. The SIRS model, in which S is the number of susceptible individuals, I is the number of infectious individuals, and R compartment denotes removed and deceased individuals (Weiss 2013), can be used to model the spread of the COVID-19 disease. The SIRS model differs from the conventional SIR model in permitting recovered individuals to re-enter the susceptible compartment (Li *et al.* 2014). In this paper, the SIRS model will be used to predict the government effort by modelling the spread of the COVID-19 disease 100 days after the MCO's 8th day. The model's output will then be compared to actual data to determine whether the model is suitable for predicting COVID-19 cases in Malaysia. This paper describes the implementation of the SIRS model for COVID-19 in Malaysia via a predictor-corrector numerical method.

2. Research Method

A quantitative study design was chosen, and data was gathered using the published paper and news from MOH. Using the compartmental structure of the SIRS model, the data is then used to develop a system of Ordinary Differential Equations (ODE). Instead of using an analytical method to solve the ODE, a numerical method (predictor-corrector method) is used. A predictor-corrector method is then used to compare the actual data to the predicted value. The predictor-corrector employs various step sizes and corrector steps. The mean absolute percentage error (MAPE) determines the success of the predictor-corrector method.

$$MAPE = \left| \frac{A_t - F_t}{A_t} \right| \times 100, \tag{1}$$

where A_t is the actual value and F_t is the forecast value. MAPE is a relative error measure that employs absolute values to prevent the cancellation of positive and negative errors. Since the relative errors are scale-independent (Kim & Kim 2016), it is possible to compare forecast accuracy for time-series data with various scales. Hence, MAPE is a suitable measure of quality for the COVID-19 cases per day in Malaysia. Note that the smallest MAPE determines the best step size and corrector step (Collopy & Armstrong 1994). The standard deviation absolute percentage error is used to further evaluate the predictor-corrector method using the SIRS model.

$$\text{percent deviation} = \left| \frac{M_t - F_t}{A_t} \right| \times 100, \tag{2}$$

where $M_t = \dfrac{\sum \text{data points}}{\text{number of data points}}$. Standard deviation is a better measure of variation than range, interquartile range, and variance (David 1998). As a result, the smaller the standard deviation absolute percentage error, the better the data.

2.1. *Mathematical model – SIRS model*

A lot of studies use the SIR model to estimate the COVID-19 cases in their country (Moein *et al.* 2021; Cooper *et al.* 2020; Rahimi *et al.* 2021). However, Ota (2020) highlights that two of four rhesus monkeys were re-infected with COVID-19 disease after confirmed recovery. Hence, it is crucial to use the SIRS model rather than the SIR model. Susceptible-Infected-

Removed-Susceptible (SIRS) model is used to illustrate the transmission of COVID-19 disease in this project. Figure 1 displays three compartments: the susceptible population that might contract the disease (S), the number of infectious individuals or active cases (I), and the removal class where the individuals have recovered or are deceased (R). Variable N is the number of populations at any time t, μ is the birth rate of the population, ν is the death rate of the population, β is the transmission rate of the disease, ε is the transfer rate of the individuals from removal compartment to re-entering susceptible class, and γ is the recovery rate. Some proportions of people from the removal class are allowed to re-enter the susceptible class at ε transfer rate to examine the effects of false detection on COVID-19 transmission dynamics.

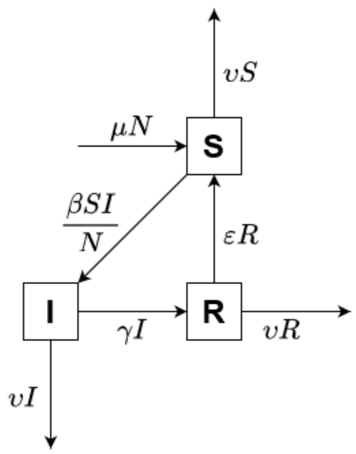


Figure 1: Compartmental structure of the SIRS model.

The SIRS model in Figure 1 generated the system of Ordinary Differential Equation (ODE) as follows,

$$\frac{dS}{dt} = \mu N - \frac{\beta SI}{N} + \varepsilon R - \upsilon S, \tag{3}$$

$$\frac{dI}{dt} = \frac{\beta SI}{N} - (\gamma + \upsilon)I, \tag{4}$$

$$\frac{dR}{dt} = \gamma I - (\varepsilon + \upsilon)R. \tag{5}$$

Consider the fact that N represents the entire population, N can be expressed in terms of S, I, and R, $N = S + I + R$. By assuming the total population to be constant, $1 = s + i + r$ where $s = S / N$, $i = I / N$, and $r = R / N$. This implies,

$$r(t) = 1 - s(t) - i(t). \tag{6}$$

Therefore, the system above consists of Eqs. (3) – (5) can be simplified into a system of two ODEs,

$$\frac{ds}{dt} = \mu - \beta is + \varepsilon(1 - s - i) - \upsilon s, \tag{7}$$

$$\frac{di}{dt} = \beta is - (\gamma + \upsilon)i. \tag{8}$$

The values for μ, υ, β, ε, and γ must be established before continuing with the system's solution. In order to create the fitted value for the parameter, a trial-and-error method must be used to determine whether it is appropriate for the data provided. However, Mohd and Sulayman (2020) had modelled a COVID-19 perspective, which resulted in the parameter values that fit the actual data of the infected population from 24th March 2020 until 23rd April 2020, as follows

$$\mu = 0.00005,\ \ \upsilon = 0.00005,\ \ \beta = 0.19,\ \ \varepsilon = 0.0009,\ \ \gamma = 0.065$$

2.2. *Application of numerical method*

Numerical techniques offer a way to get close to the answer. If the analytical method is used further, it will produce undesirable integrals. Thus, the predictor-corrector method can be used to approximate these particularly nasty integrals that defy all common calculus techniques. The Adams-Bashforth-Moulton method will be used to forecast COVID-19 cases for the 100 days after the MCO, starting with 24th March 2020. Since the Adams-Bashforth-Moulton method is a 4-step predictor-corrector method, it requires four initial values. However, there is only one initial value for each parameter. Hence, the 4th order Runge-Kutta (RK4) method is used to approximate the second, third, and fourth values with the given first initial values.

Table 1 can be used to calculate the initial values. Given the active cases on 24th March 2020, $I(0) = 1423$. On that particular day, 185 people had recovered, $R(0) = 185$ and the number of people in susceptible class S is 5798. Thus, total population, $N = 5798 + 1423 + 185 = 7406$. The initial value for this system can be written as,

$$s(0) = \frac{S(0)}{N(0)} = \frac{5798}{7406} = 0.783,$$

$$i(0) = \frac{I(0)}{N(0)} = \frac{1423}{7406} = 0.192,$$

$$r(0) = \frac{R(0)}{N(0)} = \frac{185}{7406} = 0.025.$$

RK4 method: Let $f(t,s,i) = \mu - \beta is + \varepsilon(1 - s - i) - \upsilon s$ and $g(t,s,i) = \beta is - (\gamma + \upsilon)i$. For $n = 0,1,2$, the RK4 method will be used to predict the first three values. The following is the iteration formula for value s and i,

$$s_{n+1} = s_n + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + 2k_4), \tag{9}$$

$$i_{n+1} = i_n + \frac{h}{6}(l_1 + 2l_2 + 2l_3 + 2l_4), \tag{10}$$

where $k_1 = f(t_n, s_n, i_n),$

$$
\begin{aligned}
l_1 &= g(t_n, s_n, i_n),\\
k_2 &= f(t_n + 0.5h,\ s_n + 0.5hk_1,\ i_n + 0.5hl_1),\\
l_2 &= \mathrm{g}(t_n + 0.5h,\ s_n + 0.5hk_1,\ i_n + 0.5hl_1),\\
k_3 &= f(t_n + 0.5h,\ s_n + 0.5hk_2,\ i_n + 0.5hl_2),\\
l_3 &= \mathrm{g}(t_n + 0.5h,\ s_n + 0.5hk_2,\ i_n + 0.5hl_2),\\
k_4 &= f(t_n + h,\ s_n + hk_3,\ i_n + hl_3),\\
l_4 &= \mathrm{g}(t_n + h,\ s_n + hk_3,\ i_n + hl_3).
\end{aligned}
$$

The iteration for the prediction value r could be done from Eq. (6), which is applicable to the RK4 and Adams-Bashforth-Moulton method. The following is the formula:

$$r_{n+1} = 1 - s_{n+1} - i_{n+1}. \tag{11}$$

Then for $n = 3,\ 4,\ \ldots$, the value for variable s and i will be predicted by using Adams-Bashforth-Moulton method.

Adams-Bashforth predictor method:

$$
\begin{aligned}
s_{n+1}^{0} = s_n + \frac{h}{24}\big[&55 f(t_n, s_n, i_n) - 59 f(t_{n-1}, s_{n-1}, i_{n-1})\\
&+ 37 f(t_{n-2}, s_{n-2}, i_{n-2}) - 9 f(t_{n-3}, s_{n-3}, i_{n-3})\big],
\end{aligned} \tag{12}
$$

$$
\begin{aligned}
i_{n+1}^{0} = i_n + \frac{h}{24}\big[&55 g(t_n, s_n, i_n) - 59 g(t_{n-1}, s_{n-1}, i_{n-1})\\
&+ 37 g(t_{n-2}, s_{n-2}, i_{n-2}) - 9 g(t_{n-3}, s_{n-3}, i_{n-3})\big].
\end{aligned} \tag{13}
$$

Adams-Moulton corrector method:

$$
\begin{aligned}
s_{n+1}^{k} = s_n + \frac{h}{24}\big[&9 f(t_{n+1}, s_{n+1}^{k-1}, i_{n+1}^{k-1}) + 19 f(t_n, s_n, i_n)\\
&- 5 f(t_{n-1}, s_{n-1}, i_{n-1}) + f(t_{n-2}, s_{n-2}, i_{n-2})\big],
\end{aligned} \tag{14}
$$

$$
\begin{aligned}
i_{n+1}^{k} = i_n + \frac{h}{24}\big[&9 g(t_{n+1}, s_{n+1}^{k-1}, i_{n+1}^{k-1}) + 19 g(t_n, s_n, i_n)\\
&- 5 g(t_{n-1}, s_{n-1}, i_{n-1}) + g(t_{n-2}, s_{n-2}, i_{n-2})\big].
\end{aligned} \tag{15}
$$

where k is the number of corrector steps, $k \geq 1$.

3. Implementation

A numerical analysis of the early COVID-19 disease outbreak in Malaysia will be performed using the four-step Adams-Bashforth-Moulton predictor-corrector method. The following are the steps to solve the problem:

Step 1: Pick a start date for the prediction; ideally, this should be after the MCO has started. Collect the data for number of people that infected, close contact to the infectious individuals, active cases, and total recovered people on that particular day. Then, use them to find the initial value, $s(0) = S / N,\ i(0) = I / N, r(0) = R / N$.

Step 2: Define the fitted value for the parameters: $\mu, \upsilon, \beta, \varepsilon,$ and γ . The value for the parameters needs to find using the trial-and-error method. Different starting and ending dates will result in different parameter values. Therefore, set the end date to calculate the parameters.

Step 3: Predict the first, second, and third values by using the RK4 method. Two functions must be generated for the RK4 method. $f(t,s,i) = \mu - \beta is + \varepsilon(1 - s - i) - \upsilon s$ and $g(t,s,i) = \beta is - (\gamma + \upsilon)i$ to find the values $s(n)$ and $i(n)$, for $n = 1, 2, 3$.

Step 4: Find the value $r(n)$ for $n = 1, 2, 3, \ldots$ by using $r_{n+1} = 1 - s_{n+1} - i_{n+1}$.

Step 5: Calculate the value for $s(n)$ and $i(n)$ by using Adam-Bashforth predictor and correct the solution by Adam-Moulton corrector until the difference between the corrected value and the previous corrected value is less than tolerance value. The tolerance value used in this study is 0.001.

$$\left| i_{n+1}^{k} - i_{n+1}^{k+1} \right| \leq 0.001, \tag{16}$$

Step 6: Let the iteration continue to calculate the value for $s(n)$ and $i(n)$ for $n = 4, 5, 6, \ldots$ until the final day of prediction.

In this study, the simulation of the predictor-corrector method is implemented under various step sizes. The calculation complexity increases as the step size decrease. Since smaller step size will result in more iteration, the lowest value for step size that will be used is 0.01. The step sizes that will be considered are 1.0, 0.5, 0.25, 0.1, and 0.01. Note the step size cannot be larger than 1 because it represents the ratio in a day, and $h = 1$ means the prediction of the COVID-19 cases is calculated per day whereas $h = 0.5$ means it will be calculated every 12 hours. The population size was 7406, the recovered patient was 185, the active cases was 1423, and the susceptible people was 5798. The simulation was performed on MATLAB R2022a software, and it was done on a laptop with an Intel(R) Core (TM) i5-8250U processor and 8GB RAM running Microsoft Windows 11 Home Version 10.0. With the help of the 'readmatrix' function, MATLAB can import the actual daily active cases data for Malaysia from an Excel file and plot a 2D graph using the 'matplotlib' library. Consequently, it is simple to compare predicted data with actual data. Figure 2 shows the flow chart to predict the result for COVID-19 cases by using MATLAB.

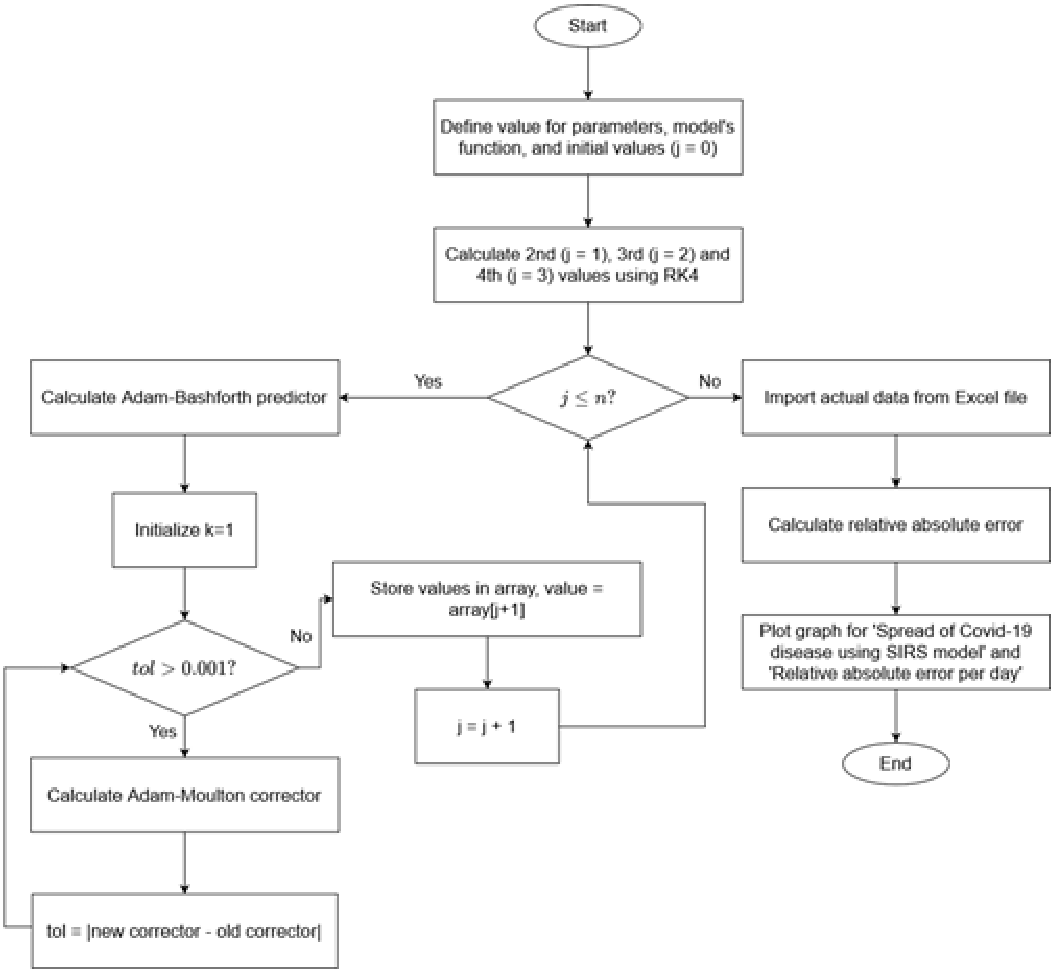


Figure 2: Flow chart for the MATLAB script file.

4. Result and Discussion

In this study, Adam-Bashforth-Moulton predictor-corrector method is incorporated with the SIRS model to simulate COVID-19 cases in Malaysia during the MCO. The SIRS model will generate a set of differential equations that must be solved numerically. Since the set of ODEs can be reduced to only 2 equations, it help to reduce the complexity of the calculation and give better performance for the model. The corrector step for the numerical method, on the other hand, will help to reduce computation error while increasing computational time.

The time series plot for the numerically computed simulation of the SIRS model is displayed on the first graph in Figure 3. The blue crosses show the actual data for the proportion of people who were infected from 24th March 2020 to 23rd April 2020, which correspond to Days 0 and 30, respectively. The black line indicates the susceptible proportion, the red line indicates the infected proportion, and the green line indicates the removed proportion. The time series plot demonstrates that the infected proportion rises steadily from Day 1 and reaches its peak on Day 15. Thereafter, it continues to fall until the graph's end. This demonstrates that the government's new order (MCO) has successfully halted the neighborhood's COVID-19 disease outbreak. Moreover, the first 30 days are crucial for putting an end to a widespread disease outbreak. To treat a new, unknown disease as soon as possible, preventive measures must be taken. The second graph displays the small relative absolute error for each day, demonstrating that the suggested model is accurate and appropriate for illustrating the COVID-19 disease's spread in Malaysia.

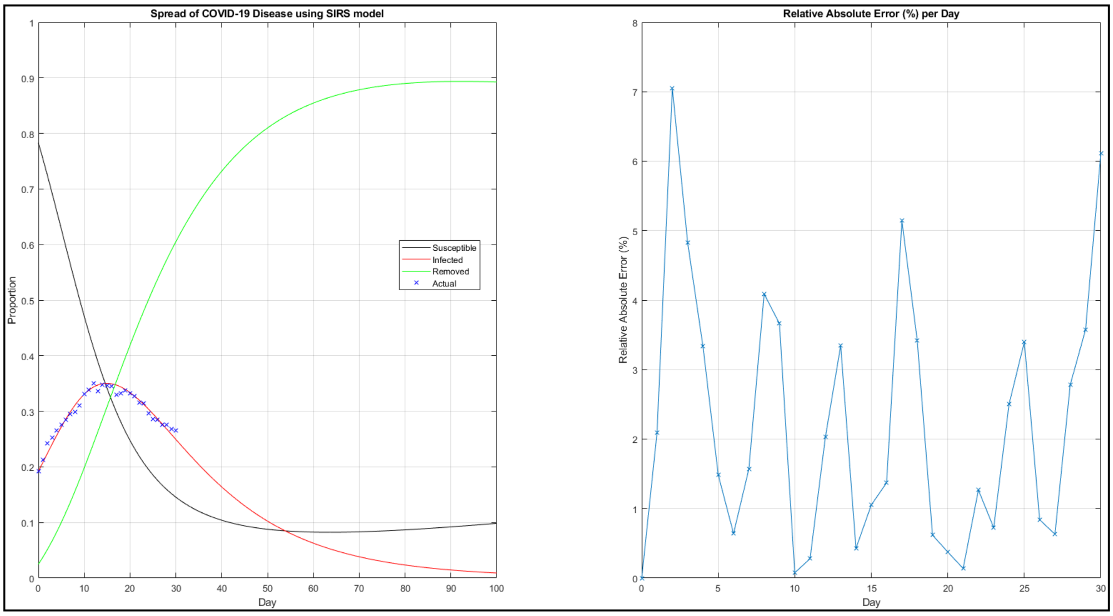


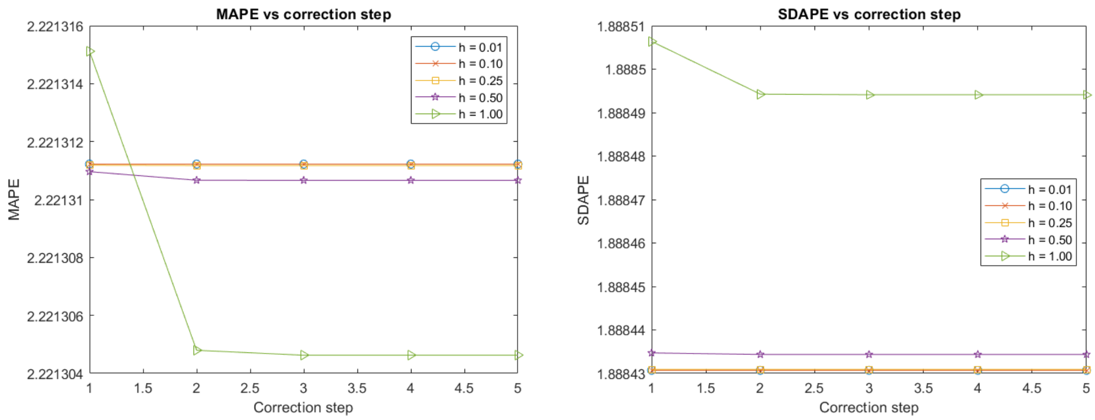
Figure 3: Time series plot of the susceptible, infected and recovered proportions for 100 days and the relative absolute error of the infected proportions for 30 days; $k = 3$, $h = 0.10$

Based on the forecast (first graph in Figure 3), if the MCO continues until 1st August 2020 (Day 100), Malaysia will be able to achieve zero cases of COVID-19. Keep in mind that the susceptible class rapidly declines as a result of the restriction to stay at home, which reduces the amount of close contact. Only family members and frontliner (health care worker, police, etc.) may be affected by COVID-19 patients. Next, the second graph shows the highest relative percentage absolute error (RPAE) per day in first 30 days with the correction step $k = 3$ and step size $h = 0.10$ is 7% and the lowest is 0.15%. Different correction steps and steps size might yields for different RPAE per day. The numerical outcomes of the Adams-Bashforth-Moulton predictor-corrector method are then compared with the data itself, using various step sizes ($h = 1.0, 0.50, 0.25, 0.10$, and 0.01). The number of correction steps is determined using the tolerance value as the iteration's stopper by applying Eq. (16). The value for maximum number of correction steps, computational time, mean absolute percentage error (MAPE), and standard deviation absolute percentage error (SDAPE) for each step size is showed in Table 2.

Table 2 shows the MAPE for various step sizes, which is approximately 2.2% for all results. The first six digits do not differ significantly. However, even minor differences can influence long-term value prediction. The standard deviation absolute percentage error is 1.9% for all results, and the first four digits do not differ significantly. Note that the maximum number of correction steps for all step sizes is two, implying that the difference between the first and second corrector values is small and less than the tolerance value. However, the computational time for each step size differs significantly, a smaller step size will result in a longer computational time as the number of iterations increases. Therefore, the optimal solution for the COVID-19 cases can be determined by using step size $h = 0.25$ and correction step $k = 2$. Please keep in mind that this parameter may not be applicable to other problems, it is only applicable to the COVID-19 in Malaysia. It is acceptable to use a higher value for the corrector step, but the difference is not significant. Figure 4 shows the MAPE and SDAPE for correction step $k = 1, 2, 3, 4,$ and 5 in the first 30 days. The result can appear more significant by plotting the graph in Figure 4 to determine how far apart the lines are from one another. According to Figure 4(a), there is a significant difference between the MAPE when the correction step $k = 1$ and $k = 2$ for step size $h = 1.00$ and $h = 0.50$. However, the MAPE value begins to converge at $k = 2$ and remains constant with higher correction steps. SDAPE values for step size $h = 1.00$ and $h = 0.50$ differ from other step sizes, which is inconsistent for the first and second corrector steps. Next, the step size for $h = 0.25, h = 0.10,$ and $h = 0.01$ yield to same value for both MAPE and SDAPE. This demonstrates that even when a smaller step size is used, SDAPE and MAPE still yield the same value. Therefore, the proposed model should use step size $h = 0.25$ and the number of correction steps $k = 2$ because the numerical results are more reliable with only a slight loss in accuracy and save computational time without the need to use a smaller step size or iterate more correction loops during each time step.

Table 2: Measurement for each step size

Step size	Max number of correction steps	Computational time (sec)	MAPE	SDAPE
1.00	2	0.000249	2.221315116	1.888506386
0.50	2	0.000479	2.221310962	1.888434705
0.25	2	0.001861	2.221311184	1.888430914
0.10	2	0.002483	2.221311222	1.888430704
0.01	2	0.027182	2.221311223	1.888430699



(a) Graph of MAPE vs correction steps (b) Graph of SDAPE vs correction steps

Figure 4: Graph of MAPE and SDAPE against number of correction steps in first 30 days

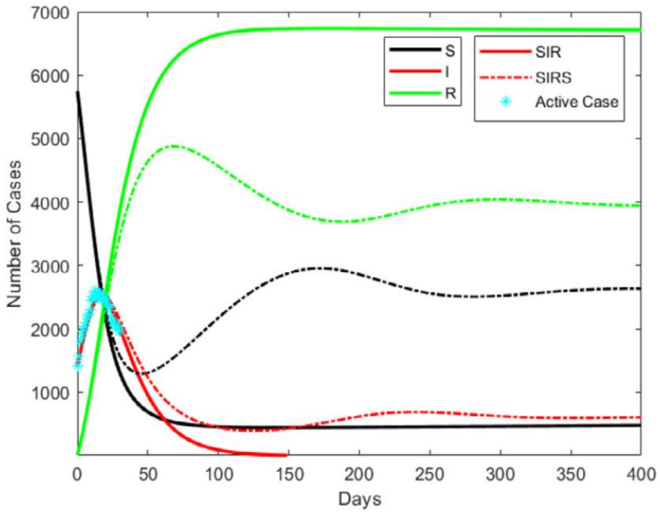


Figure 5: The predictions of SIR and SIRS models for 400 days, Day 0 – 24th March 2020 (Mohd & Sulayman 2020)

To further measure the outcome, let's compare the result with Mohd & Sulayman (2020) that attempts to solve the SIRS model using an analytical approach. Since this study only uses the SIRS model to predict COVID-19 cases, we will only compare the graphs represented by dotted lines. It is worth noting that the graph shape in Figure 5 for the first 100 days is identical to the graph shape in Figure 3. Therefore, the analytical method and the proposed numerical method can be assumed to produce the same value. According to Figure 5, even though the SIRS model is using an analytical method, there are still some errors, and thus the error that we calculated earlier could be due to the SIRS model. As a result, the multi-step predictor-corrector method is accurate enough to compute the SIRS model while also reducing calculation complexity. The complexity of the problem affects computation time. Complex problems are difficult to solve analytically, and some problems lack precise values. Therefore, a numerical approach is necessary to approximate a problem without finding an exact solution. Even so, multi-step numerical method will provide greater accuracy. A study by Hratchian (2004) prove that the predictor-corrector method will improve stability and accuracy to get better convergence characteristics because it combines an explicit and implicit technique. Da Silva *et al.* (2020) shows that a multi-step mechanism involving deconvolution and isoconversional methods can provide a better approximation of biomass experimental data than a single-step mechanism.

There are numerous predictor-correctors available in numerical methods other than Adam-Bashforth-Moulton, including Euler method with the trapezoidal rule, Predict–Evaluate–Correct–Evaluate (PECE) mode, and others. However, a lot of study prefer to use Adam-Bashforth-Moulton method because of the less complexity and high accuracy. Adam-Bashforth-Moulton truncation errors are solely determined by the corrector's characteristics at each step, and error propagation is solely dependent on the corrector equation (Crane & Klopfenstein 1965). The predictor's sole purpose in this case is to calculate an error estimate. Both the predictor equation and the corrector equation are of fourth order, both independently and jointly. For instance, (Deng *et al*. 2022) use this method in Convolutional Neural Networks (CNN) for fire detection because of the high accuracy.

5. Conclusion

The paper presents the prediction of COVID-19 cases for 100 days by using the predictor-corrector method. We demonstrated that the accuracy of the Adam-Bashforth-Moulton predictor corrector method can be addressed in the context of COVID-19 case prediction using the SIRS. The power of this technique can be seen clearly when computing the percentage of the mean and standard deviation for relative absolute error. The different value for step size and corrector step for the numerical method has been used to show various levels of accuracy. The MAPE for all solutions is 2.2%, and the standard deviation for relative absolute error is around 1.8%. As a result, it does not differ significantly when the step size is set between 0.25, 0.10 and 0.01. Setting the step size as small as possible while avoiding unnecessary iterations is advised when solving a system of ODEs numerically in order to increase the accuracy of the numerical simulation results. It is also recommended to use the appropriate correction step to correct the solution in order to reduce its relative absolute error using a pair of predictor-corrector numerical models, because smaller step sizes and more correction steps may result in an increase in computational time and cost.

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School of Mathematical Sciences
Universiti Sains Malaysia
11800 USM,
Pulau Pinang, MALAYSIA
E-mail: rusyidahazri@student.usm.my, saratha@usm.my, junnamc@student.usm.my, yihangtan98@student.usm.my*

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*Corresponding author