PROJECT REPORT

Computational Physics 2

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Analysis for obtaining SIR model for spreading of COVID -19 in a country (NIGERIA)

Abstract: The aim of this study is to predict the daily infected cases with Coronavirus (COVID-19) in Nigeria. We apply the SIR model on data from 25 February 2020 to 24 April 2020 for the prediction. Following Huang et al 11, we develop two SIR models, an optimal model and a model in a worst-case scenario COVID-19. Based on the simulation of the two models, the epidemic peak of COVID-19 is predicted to attain 24 July 2020 in a worst-case scenario, and the COVID-19 disease is expected to disappear in the period between December 2020 at the latest. We suggest that Nigeria authorities need to implement a strict containment strategy over a long period to successfully decrease the epidemic size.

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Introduction:

On 31 December 2019, a cluster of cases of pneumonia of unknown cause was detected in Wuhan City, Hubei Province of China 25. The Chinese authorities identify on 7 January the coronavirus disease (COVID-2019) as the causative virus 25 . This epidemic continues to cause infections in other Chinese cities and in multiple countries around the world 23. On 01 April 2020, the World Health Organization (WHO) has reported a total of 823611 confirmed cases of COVID-19 infection with 40534 death cases worldwide 26. The transmission of COVID-19 takes place by inhaling the respiratory droplets coming from the coughing or sneezing of an infected person.

the first three cases were reported on 25 february, 2020 in Nigeria, The epidemic continues to spread in other regions of the country. To prevent the spread of COVID-19 infections, a nationwide shutdown, in the guise of a general public holiday, went effective on March 3 and continued until august. Various earlier studies have predicted the confirmed cases of COVID-19 infection in different countries.

Kuniya16 applied the well-known SEIR compartmental model to predict the epidemic peak of COVID-19 disease in Japan. He used data of daily reported cases of COVID-19, from15 January to 29 February 2020. He founds that the epidemic peak in Japan could possibly reach the early-middle summer. Roosa et al 24 forecast the covid-19 epidemic in China over a short-term period using generalized logistic growth model, the Richards growth model, and a sub-epidemic wave model. They employed data of cumulative confirmed cases between January 22, 2020 and February 9, 2020. They found that the epidemic has reached saturation in Hubei and other provinces of China. Hamidouche 7, introduce the Alg-COVID-19 Model to predict cumulative cases of COVID-19 in Nigeria. This model allows predicting the incidence and the reproduction number Ro in the upcoming months.

According to his results, the number of infected cases in Nigeria will exceed 5000 on 07 April 2020 and it will double to 10000 on 11 May 2020 7. This study applies the Susceptible-Infected-Removed (SIR) model without demographics (no births, deaths, or migration) to predict the daily confirmed cases of COVID-19 infection in Algeria.

We use data of reported confirmed cases between march 8, 2020 and July 24, 2020. We predict the epidemic peak and the end-date of this disease using an optimal SIR model and an SIR model in a worst-case COVID-19 scenario.

These results could be helpful for decision makers in the respective country to implement their future counter strategies to COVID-19 outbreak.

Method:

1) Model:

The SIR model without demographics is given by the following non linear system of ordinary differential equations

$$\frac{dS(t)}{dt} = \beta S(t)I(t)$$

$$\frac{dI(t)}{dt} = \beta S(t)I(t) - \gamma I(t) \qquad (1.1)$$

$$\frac{dR(t)}{dt} = \gamma I(t)$$

The function S(t) represents the number of **susceptible** cases at time t. The function I(t) represents the number of **infected** cases at time t, and the function R(t) is the compartment of **removed** cases from the disease, where:

Removed cases = Death cases + Recovered cases.

The parameters **β** and **γ** are called the **contact rate** and the **removed rate**, respectively.

The initial condition of this model S(0) ,I(0),R(0) must satisfy the condition, S(0) +I(0)+R(0)=N. where N is the population size.

The model can be written also as follows:

$$\frac{dS(t)}{dt} = \beta \frac{S(t)}{N} I(t)$$

$$\frac{dI(t)}{dt} = \beta S(t)\frac{I(t)}{N} - \gamma I(t) \qquad (1.2)$$

$$\frac{dR(t)}{dt} = \gamma I(t)$$

With $\frac{S(t)+I(t)+R(t)}{N} = 1$ and $S(0)>0$, $I(0)>0$,$R(0)= 0$

The basic reproductive ratio R_o is' the average number of secondary cases arising from an average primary case in an entirely susceptible population, and it's given by β/γ.
We integrate numerically our non-linear system using Runge- Kutta method for Ordinary Differential Equations . This algorithm handles stiff and non stiff systems of size N, with general form .

Following Huang et al 11, we consider two SIR models:

The first one is an **optimal model**, where we suppose that the initial population size N is equal to the total of confirmed cases in Nigeria.

In the **second SIR model** we assume that whole real population in Nigeria is susceptible, with high contact rate β and high removed rate γ (either recovered or died). This is the **worst-case scenario**, and this model could be used to predict the largest infections of the epidemic.

Python software version 3.6.4 was used to implement the SIR model and solve it.

Empirical results:

The data were obtained from Johns Hopkins University, Center for systems science and engineering 10. We used the number of daily new confirmed cases for the COVID-19 epidemic in Nigeria, from 25 February 2020 to 24 April 2020.

Firstly we fit the optimal SIR model. We used equation (1.2) with initial parameters , and initial conditions

$$I_0 = \frac{I(0)}{N} = \frac{1}{N}$$

$$S(0) = 1 - I_0$$

$$R(0)=0$$

With, N=3127 ,equal to the total confirmed cases till 24 April 2020. Solving the SIR system we will use the parameters $\beta = .3$ and $\gamma = .1$ and .

Thus the basic reproduction number is given by: $R_0 = \frac{\beta}{\gamma} = \frac{.3}{.1} = 3$

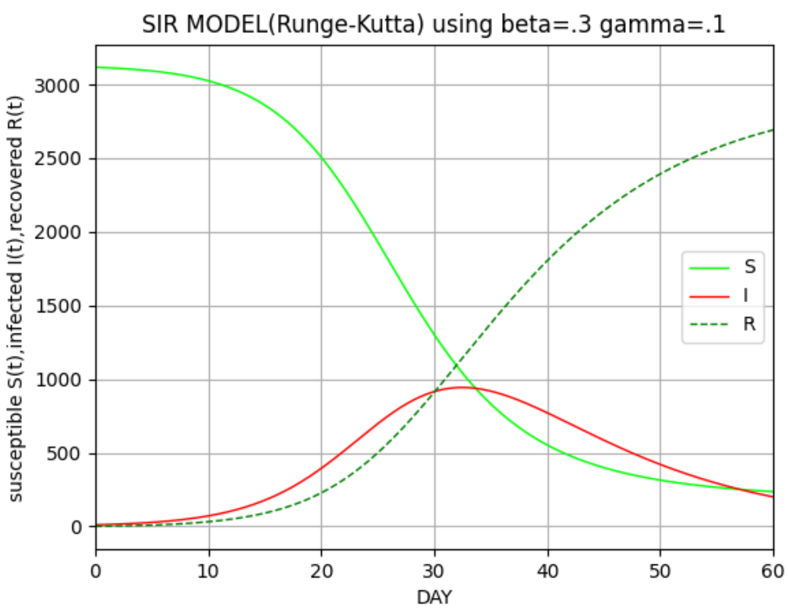


Figure 1 shows the predictions of the number of daily new infected cases with COVID-19 in Nigeria, by fitting the optimal SIR model.

The mean absolute error (MAE) is used to evaluate the accuracy of this model, where:

$$MAE = mean(| y_t , I_t|)$$

y_t is the real numbers of daily infected cases of COVID-19 in Nigeria.

y_t is the real reported value at time t and I_t is the predicted value at the same time t .We get MAE =14 as accuracy of the optimal SIR model for the prediction of new infected cases.

Concerning the **second model** in a worst-case scenario COVID-19, we reset the initial parameters as follow:

β,as a high contact rate. 0.95
γ,as a high removed rate (either recovered or death cases). 0.75
The real population size of Nigeria 3127987666.
We proceed as before,with the parameters β = .9 ,γ =.2 , Thus R_o= 4.5

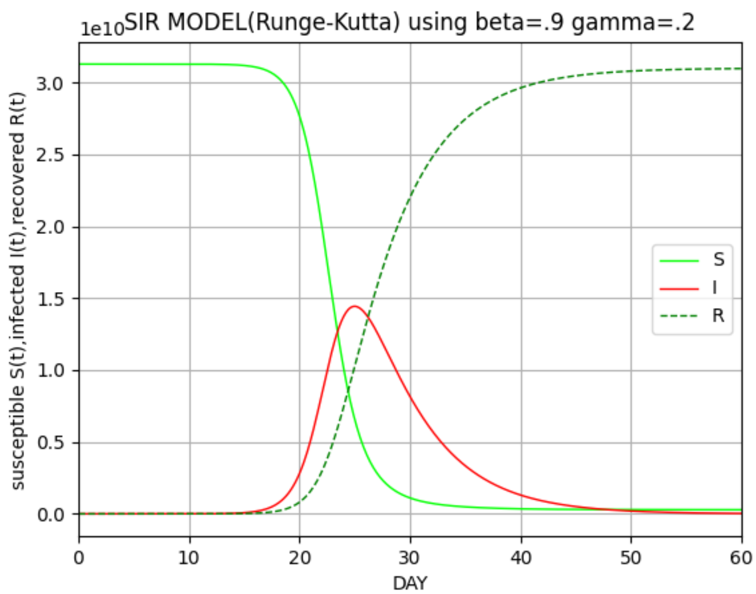
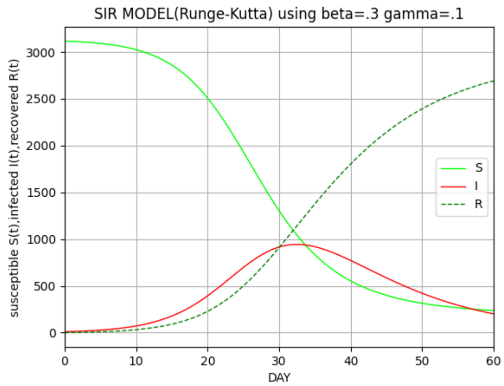


Figure 2 shows the simulation of infected cases with COVID-19 in a worst-case scenario. We get MAE =30 as accuracy of this model. We remark that the predicted number of infected cases with COVID-19 in Nigeria increase exponentially fast in this case.



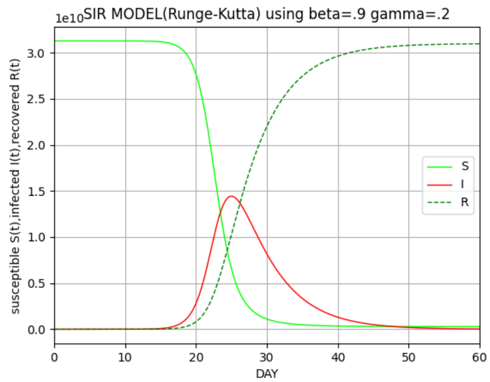


Figure .3 :The prediction of the epidemic peak of COVID-19 in Nigeria using both models is shown in Figure 3.

We extract from this Figure that the predicted epidemic peak would be around 25 July 2020 at the latest, with about infections, in a worst-case scenario.

The predicted epidemic peak based on the optimal SIR model was on 13 April 2020 with 106 infections. The end-date of COVID-19 in Nigeria is estimated to be around 16 November 2020 in a worst-case scenario, and around 18 September 2020 based on the optimal SIR model predictions. We can remark easily the large differences in the predicted infections between the two models.

These differences represent the potentially preventable infections as a result of containment strategies.

Discussion :

This shows the importance of containment strategies and how many COVID-19 infections can be prevented by these strategies. Stand on these results; we conclude that the COVID-19 epidemic will continue to spread in Nigeria for about six upcoming months, at the latest.

Conclusion:

In this study we predict the COVID-19 epidemic outbreak in Nigeria using the number of daily infected cases, from 25 February 2020 to 24 April 2020.

We have developed two SIR compartmental models without demographics, an optimal model and a model in a worst-case scenario. The value of the basic reproduction number *Ro* using the optimal SIR model is 3.0, while *Ro* is estimated to be equal to 4.5 in the worst-case scenario COVID-19.

Ro has a various determinants such as social behavior, population structure, viral evolution, environment, immunity as well as immigration policies, healthcare and Infrastructure of the health sector.

Comparing the prediction results of both models, we find that the COVID-19 epidemic peak in Nigeria might attain 24 July 2020 with about 2444102 infections in a worst-case scenario. The end of this epidemic in Nigeria is expected to be between 18 September 2020 and 16 November 2020, at the latest.

Following Kuniya 16 and based on the large differences in the predicted infections between the two models that represent the potentially preventable infections, we suggest that a strict containment strategy is needed in Nigeria as soon as possible, over a relatively long period, in order to decrease the epidemic size.

Fuerther work :

In perspective, we will try to capture the effect of quarantine measures on COVID-19 outbreak in Nigeria. For this, we would like to apply the SIQR model (Q stands for quarantined) 19.

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