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Epidemiological Characteristics of COVID-19 Ongoing Epidemic in Iraq

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ABSTRACT

Summary Epidemic models have been widely used in different forms for studying and forecasting epidemiological processes such as the spread of HIV, SARS, and influenza, and recently, the 2019–20 coronavirus which is an ongoing pandemic of coronavirus disease 2019 (COVID-19), that caused by severe acute respiratory syndrome coronavirus 2 (SARSCoV-2). To find the epidemic tendency and the main metrics of the outbreak of COVID-19 in Iraq.

Method We considered a generalized SEIR model to simulate the ongoing spread of the disease and forecast the future behavior of the outbreak. The dynamical model based on seven compartments to describe the states of the epidemic. The model parameters were estimated using particle swarm optimization (PSO) algorithm, to get the best fitting for the real cumulative quarantined cases, recovered cases and death cases collected from the official authority reports in Iraq for the period from February 27 2020 to April 1 2020.

Findings Main characteristic of the ongoing in Iraq are determined, epidemic inflection point, the basic reproduction number, the expected cumulative number of the quarantined case and exposed and infectious cases are presented.

KEYWORDS COVID-19, Epidemiological model, PSO, Reproduction number, Inflection point, Iraq.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) was first identified in Wuhan, Hubei, China, in December 2019, and was recognized as a pandemic by the World Health Organization (WHO) on 11 March, is rapidly spreading in China [1] and 196 countries and territories over last three months. COVID-19 has multiple characteristics distinct from other infectious diseases, including high infectivity during incubation, the time delay between real dynamics and daily observed number of confirmed cases, and the intervention effects of implemented quarantine and control measures. The incubation period of COVID-19 is reported to be 3-7 days, at most 14 days, which varies greatly among patients [1]. The novel coronavirus is believed to be infectious during incubation period when no symptoms are shown on the patients [2], an important characteristic differentiating COVID-19 from its close relative SARS.

During the study of epidemics, one of the most significant and challenging problem is to forecast the future trends, like how many individuals might be infected each day [3,4,5], when the epidemics stop spreading, what kinds of policies and actions have to be taken and how they influence the epidemics, and so forth [6, 7, 8]. After the outbreak of an epidemic, all actions of individuals and government heavily depend on our understandings on its future trend. The SARS in 2003 [9], H1N1 flu in 2009 [10] and recent COVID-19 are several well-known examples.

Epidemic modeling date back to the early twentieth century, to the 1927 work by Kermack and McKendrick, whose models were used to study the plague and cholera epidemics [11,12]. Epidemic modeling is nowadays a powerful tool for investigating human infectious diseases, such as Ebola and SARS contributing to the understanding of the dynamics of virus, providing useful predictions about the potential transmission of the virus and the effectiveness of possible control measures, which can provide valuable information for public health policy makers [13, 14, 15].

Since the accurate epidemic forecast is so critical, there are diverse methods reported in the literature to try to achieve this goal [16]. Among them, empirical functions, methods based on statistical inference and dynamical models (difference equations, ODEs and PDEs) are three major routines [5]. Empirical functions, especially those with explicit forms, are most popular ones. They are simple, easily understandable, fast implemented and analyzable. So many merits lay down the unreplaceable role of empirical functions in this field. The statistical inference methods are also highly welcomed, especially in the presence of a large amount of first-hand data. The basic goal of most statistical methods in epidemics is to estimate the basic reproduction number, which serves as a key quantity to evaluate the future trends of an infectious disease.

In dynamical models, the basic reproduction number is transformed into reaction coefficients. Based on compartment assumptions on populations involved in dynamical modeling epidemics, it shows a great ability to correctly reproduce the basic features of the spreading process of infectious disease, to reveal the hidden dynamics, like the numbers of exposed cases and asymptomatic carriers which are hard to be learnt from usual epidemiology investigation, to forecast the future trends of epidemics, as well to evaluate the influence of diverse control policies and actions against the spreading of infectious diseases in quantity [5, 17].

METHOD

In this paper we collected the epidemic data of the corona virus COVID-19 time series in Iraq and then applied a generalized SEIR dynamical model to analyze the data and give epidemiological characteristics and the epidemic figures and expected the state of the situation. The model parameters are estimated using particle swarm optimization PSO method. Main epidemic metrics like latent time, quarantine time, basic reproduction number, inflection point, ending time and total infected cases are determined. The paper is organized as follow, section (2) gives the mathematical model details. In section (3) we present the parameters inference methodology. Section (4) presents the simulation results of the proposed model and the epidemic tendency. In section (5), the conclusion and discussion of the results and the epidemic metrics are given.

THE PROPOSED MODEL

Mathematical models can project how infectious diseases progress to show the likely outcome of an epidemic and help inform public health interventions. Models use basic assumptions and/or collected statistics along with mathematics to find parameters for various infectious diseases and use those parameters to calculate the effects of different interventions. The modeling can help decide which intervention/s to avoid and which to trial, or can predict future growth patterns. The most commonly implemented dynamical model in epidemiology are the SEIR models. The SEIR model consists of four compartments: Susceptible individuals $S(t)$, Exposed individuals $E(t)$ (infected but not yet be infectious, in a latent period), Infectious individuals $I(t)$, and Recovered individuals $R(t)$. Where many infectious diseases have an exposed period after the transmission of the infection from susceptible to potentially infective members, but before these potential infective can transmit infection [18, 19, 20, 21].

To describe the dynamics of the infectious disease of the COVID-19 outbreak in Iraq, we will use a generalization of the classical SEIR model by incorporating new three classes which are $P(t)$, $Q(t)$ and $D(t)$, which respectively stand for insusceptible cases, quarantined cases (confirmed and infected), recovered cases and closed cases (or death) which proposed by [17]. The model diagram is shown in Fig. 1 which can be described by ordinary differential equations given by:

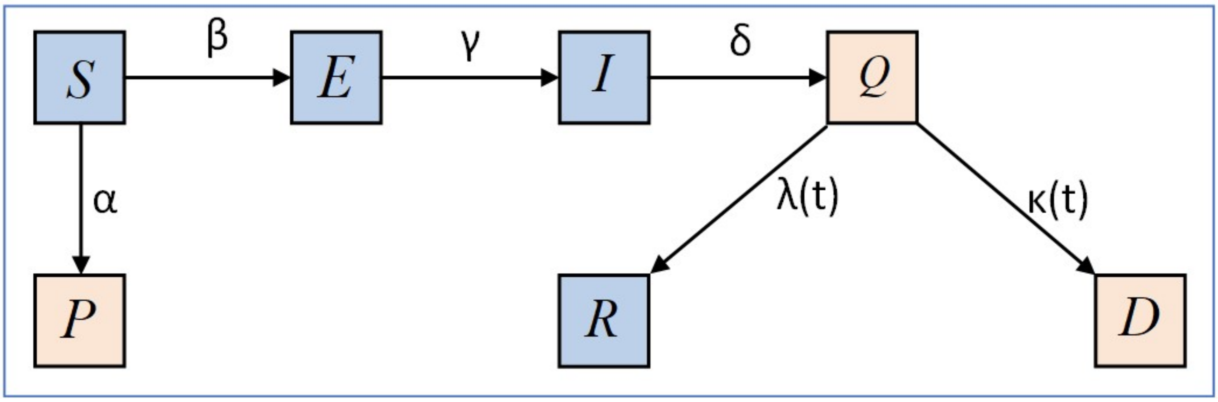


Fig. 1: Block diagram representation of the SEIR-QD dynamical model (1), with seven compartments representation.

$$
\begin{aligned}
\frac{dS(t)}{dt} &= -\beta\frac{S(t)I(t)}{N} - \alpha S(t) \\
\frac{dE(t)}{dt} &= \beta\frac{S(t)I(t)}{N} - \gamma E(t) \\
\frac{dI(t)}{dt} &= \gamma E(t) - \delta I(t) \\
\frac{dQ(t)}{dt} &= \delta I(t) - \lambda(t)Q(t) - \kappa(t)Q(t) \\
\frac{dR(t)}{dt} &= \lambda(t)\,Q(t) \\
\frac{dD(t)}{dt} &= \kappa(t)\,Q(t) \\
\frac{dP(t)}{dt} &= \alpha S(t)
\end{aligned} \tag{1}
$$

where

$$N(t) = S(t) + E(t) + I(t) + Q(t) + R(t) + D(t) + P(t), \tag{2}$$

is the population total number which is considered as constant. Based on the growing number of cases worldwide within a short period, the disease is assumed to be spread sufficiently fast compared to the birth and the natural death rates, then can be considered as negligible in the model, so that:

$$\frac{dS(t)}{dt} + \frac{dE(t)}{dt} + \frac{dI(t)}{dt} + \frac{dQ(t)}{dt} + \frac{dR(t)}{dt} + \frac{dD(t)}{dt} + \frac{dP(t)}{dt} = 0 \tag{3}$$

The model parameters definition are as follows: α represents the protection rate, β the infection rate, γ^{-1} is the average latent time, δ^{-1} represents the quarantine time, $\lambda(t)$ the cure rate and $\kappa(t)$ is the mortality rate. Since the model (1) monitors human populations, all its associated parameters are nonnegative. The basic reproduction number of the infection that used to measure the transmission potential of a disease such that the infection will be able to start spreading in a population or not. The basic reproduction number can be given by:

$$R_0 = \beta\delta^{-1}(1-\alpha)^{\mathrm{T}} \tag{4}$$

Table 1: Estimated values of the system (1) parameters, using the PSO algorithm.

Parameter	Description	Value
N	Population (million)	40
α	Protection rate	0.0100
β	Infection rate	0.6310
γ^{-1}	Latent time (day)	2
δ^{-1}	Quarantine Time (day)	4.126
E_0	Initial exposed case	5
I_0	Initial infection case	8

where T is the number of days.

PARAMTER INFERENCE

It is worth noting that $\lambda(t)$ and $\kappa(t)$, the cure rate and the mortality rate of the infectious disease respectively, are considered time dependent according to the public health procedure followed by the society. Therefore, there are four parameters to be estimated β, α, γ and δ in addition to the two initial values of the exposed variable E_0 and the infectious variable I_0. While the other variables initial values are fetched from the data time series.

METHOD AND DATA The data series of the quarantined cases, recovered cases and the closed cases are found from the daily official reports of Iraqi government and the WHO reports. The PSO algorithm has been used to estimate the dynamical model parameters so that the model response fits the public data time series. In this work, we will consider the latent time which is generally estimated in several days [22, 23, 24], to be fixed as two days as reported in [17]. The results of the parameters estimation are given in Table 1, and the average relative error used as a loss function during the PSO parameter estimation is given by:

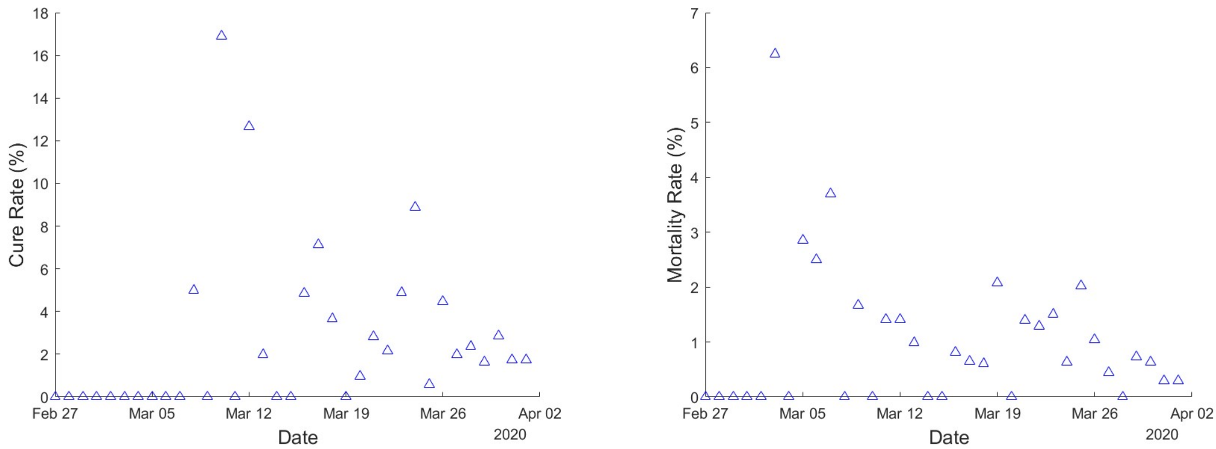
$$err = \sqrt{\frac{\|\hat{c} - c\|_2}{\|c\|_2}} \tag{5}$$

where $\hat{c}$ is the prediction and c is the public data, which is applied on the cumulative quarantined cases. The relative error found equals to 3.84%.

SIMULATION AND RESULS

In this section, the generalized SEIR-QD model (1) has been solved numerically by using the estimated parameters in Table 1. In Fig. 2, we have plotted the cure rate which is the ratio of the new recovered cases to the currently confirmed cases and mortality rate which is the ratio of the new deaths to daily confirmed cases as a function of time. It is clear that these rates are changed with time and evolve with the progress of the infectious disease, and reflect directly the public health conditions.

In Fig. 3, the dynamical model output is fitted to the time series data of corona virus epidemic in Iraq which collected from medical records, epidemiological investigations and official websites. The results reveal a good representation of the actual epidemic quarantine, recovered and death time series.



(a) (b)

Fig. 2: The epidemic cure and mortality characteristics: (a) Cure rate; (b) Mortality rate.

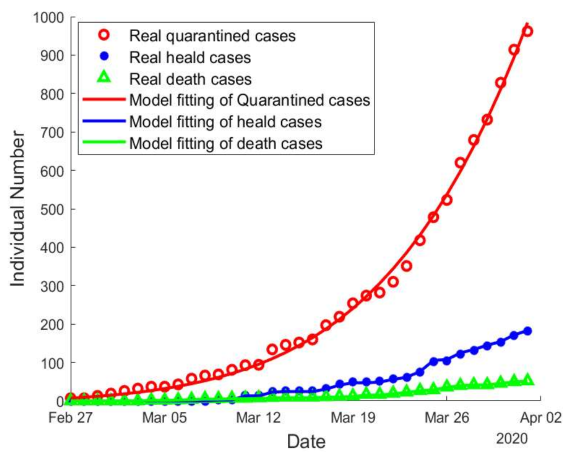


Fig. 3: The SEIR-QD model (1) fitting to the actual collected time series of the epidemic.

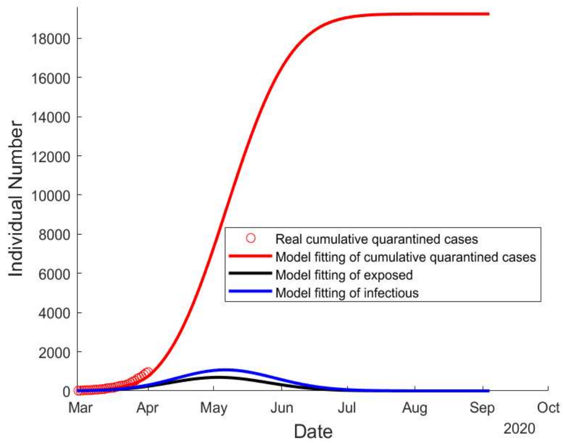
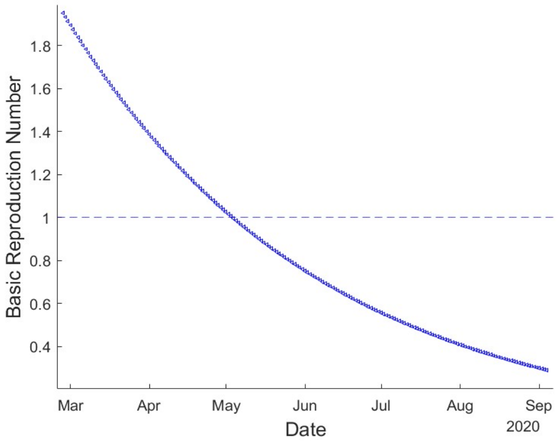


Fig. 4: The forecast of epidemic growing tendency for cumulative quarantined cases, exposed cases and infectious cases through model (1).

In Fig. 4, the simulation is implemented for 190 days and it is observed that under the current control measure the disease will run its course from the onset date of the first case until 03-May-2020 when the maximum number of infected cases is reached. Also, it is clear that the current situation show somewhat flat curve duo to the applied curfew and movement control.

In Fig. 5, the basic reproduction number is depicted. It is clear that the basic reproduction number will cross the unity at 3-May-2020, where the epidemic starts to decrease after this date. To investigate the effect of variation in the latent time γ^{-1}, on the epidemic metrics, Fig. 6 depicts the cumulative quarantined cases for different values of the latent time, while Fig. 7 presents the corresponding exposed plus infected cases. One can observe that the cumulative quarantined, the exposed and infectious cases are increasing with the latent time, which consistent and reasonable [17].



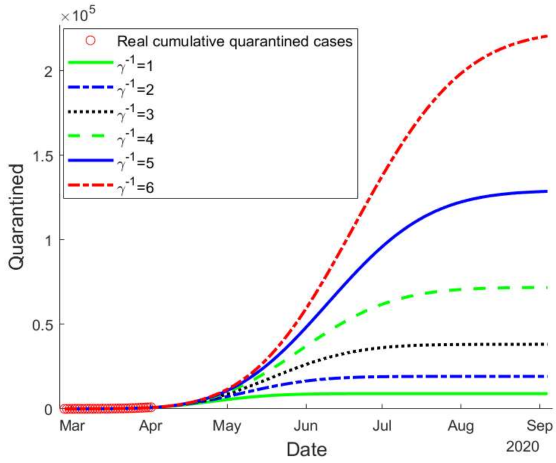


Fig. 5: Basic reproduction number of the proposed model (1).

Fig. 6: Cumulative number of the quarantined individuals for different values of the latent time γ^{-1}.

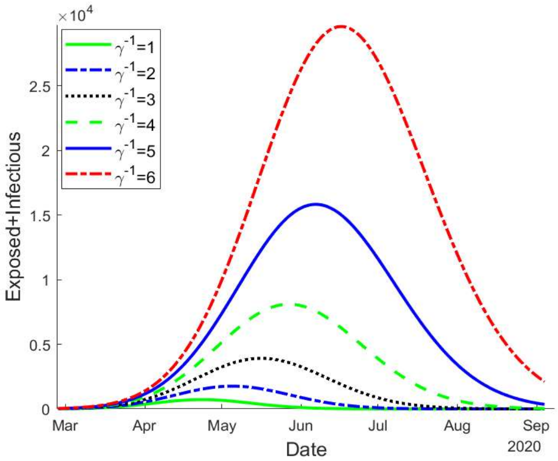


Fig. 7: The sum of exposed and infectious cases for different values of the latent time γ^{-1}.

CONCLUSION

We applied the previously described SEIR-QD model to interpret the collected public data on the cumulative numbers of quarantined cases, recovered cases and closed cases from Feb. 27th to Mar. 26th, which are published on a daily basis by the ministry of health in Iraq. The optimal values for unknown model parameters and initial conditions, which best describe and fit the real cumulative numbers of quarantined cases, recovered cases and closed cases, are determined using the particle swarm optimization algorithm and summarized in Table 1.

The model is found to be accurate as it is able to fit real cases time series in Iraq. Moreover, the model presents the forecast evolution course of the COVID-19 and the epidemic trend. The results show a slow epidemic dynamic due to the government control actions to prevent the virus spreading include the efforts of travel restrictions, quarantines, curfews, workplace hazard controls, event postponements and cancellations, and facility closures., which are needed to reduce the total number of the infected individuals. The expected figures show the seriousness of the spread of the disease if there is no appropriate control measure is taken. The epidemic characteristic metrics like the total quarantined case, basic reproduction number and the cure and mortality rates are also presented in the results.

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