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Design of a Quarantine SITR Model Using the Novel Coronavirus Dynamics

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Abstract: This present study presents the mathematical dynamics of a new nonlinear quarantine SITR model based on the novel coronavirus (COVID-19). This study aims to investigate a mathematical model for coronavirus (COVID-19) and reveal its associated results. These studies collectively describe the social, psychological, interactive, behavioral, and mental health impacts of the novel coronavirus pandemic on people worldwide by using an efficient quarantine SITR model based on the most popular iterative scheme Runge-Kutta Method. The novelty of this attempt is that this model is defined as susceptible (S) class, infected (I) class, treatment (T) class, and recovered (R) class, i.e., quarantine SITR model. Furthermore, the class quarantine is also introduced in the model as the treatment subclass. The brief feature of each class is explained along with the explanation of each factor. In order to solve this new nonlinear quarantine SITR mathematical model, the famous Runge-Kutta numerical scheme is applied. Moreover, some plots based on the new nonlinear quarantine SITR model using different parameter values indicate the existing details of this dangerous novel COVID-19. For example, the graphs of the susceptible people are decreasing, while those susceptible people who have some diseases or have old age are getting higher up to dangerous levels. This real evidence indicates the exactness of the new nonlinear quarantine SITR model.

Keywords: quarantine SITR model, coronavirus, Runge-Kutta scheme, treatment, diseases.

基于新型冠状病毒动力学的检疫“易感类、感染类、治疗类、康复类”模型设计

摘要：本研究提出了一种基于新型冠状病毒的新型非线性隔离易感感染治疗恢复模型的数学动力学。本研究旨在调查冠状病毒的数学模型并揭示其相关结果。这些研究通过使用基于最流行的迭代方案龙格-库塔方法的有效隔离易感感染治疗恢复模型，共同描述了新型冠状病毒大流行对全世界人民的社会、心理、互动、行为和心理健康影响。这种尝试的新颖之处在于，该模型被定义为易感（小号）类、感染（一世）类、治疗（吨）类和恢复（R）类。此外，模型中还引入了类隔离作为治疗子类。每个类的简要特征与每个因素的解释一起解释。为了求解这种新的非线性隔离易感感染治疗恢复数学模型，应用了著名的龙格-库塔数值方案。此外，基于使用不同参数值的新型非线性隔离易感感染治疗恢复模型的一些图表明了这种危险新型新冠肺炎的现有细节。例如，易感人群的曲线图在下降，而那些患有某些疾病或年老的易感人群正在上升到危险水平。这一真实证据表明了新的非线性隔离易感感染治疗恢复模型的准确性。

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关键词：隔离易感-感染-治疗-康复模型, 冠状病毒, 龙格-库塔方案, 治疗, 疾病。

1. Introduction

Since its birth, human life has faced various challenges and obstacles in floods, earthquakes, diseases, etc. As for some widespread diseases like dengue fever, a mosquito-borne disease produced by the dengue virus. It extensively spreads in Africa, South and Central America, the Eastern Mediterranean, the Caribbean, Southeast and South Asia, and Oceania regions. It is a very serious disease, and almost half a million infected with dengue virus people are hospitalized every year, but most of the patients recover after a few days. Some major symptoms of this fever are high fever, vomiting, headache, joint pains, and muscle. Ebola is another infectious, dangerous that has killed several people globally, and it transmits into humans from animals. Another world deathly disease is HIV, which converts from chimps to people. This transferred viral dis-ease was mysterious at the end of the last century and infected almost 300,000 persons. Lassa was a very dangerous fever and is believed to transmit in people from rates. Some other diseases are created through the communications of other living beings to people. Therefore, several medical functions have been established by humans and applied many procedures to prevent the reported diseases.

Recently, the world has suffered a dangerous and deathly disease called coronavirus (COVID-19), a spreading virus-producing respiratory infection. COVID-19 is a highly shifted disease from one person to another through small droplets of the mouth or nose that spread from a deceased person's exhales or coughs [1]. Many people are infected, and the death ratio increases day by day from this virus. The deathly COVID-19 was reported for the first time on December 31, 2019, in Wuhan city, the Hubei province of China [2]. Currently, there is no treatment or vaccine for COVID-19, and it has become a big task for all the countries to control it. In Wuhan, China, many people were killed through the COVID-19, and then the Chinese government lockdown the infected cities and quarantined the diseased people. In developing countries, the number of infected cases is in the thousands, and the reported deaths in Italy, Spain, England, and America have increased from China. The key symptoms of this virus are dry cough, fever, and tiredness. However, other symptoms are shortness of breath, aches/pains, sore throat, and some people will report runny noses, nausea, or diarrhea. These stated symptoms are generally minor and start slowly. Most people (around 80%) infected with the COVID-19 have recovered without special treatment. However, one infected person out of six from COVID-19 gets seriously ill and feels difficulty breathing. COVID-19 badly affects older people (almost age 60 or more) and those facing serious medical diseases like cardiovascular disease, diabetes, chronic respiratory and cancer. Those with fever, breathing difficulty, and dry cough should pursue medical care.

The spreading ratio of the COVID-19 is very problematic and has become a worry for the whole world. To present the mathematical model is another task while predicting the outcomes of this disease is very frustrating for the authors. One of the main predictions is that if this disease spreads to animals or birds, then how we can control it. The proper vaccine should be discovered; otherwise, the world should be ready to face many more new challenges like human loss, food shortage, unemployment, poverty, and many more. The number of COVID-19 cases has been reported at 1,374,605, the recovered people are 294,319, and the reported number of deaths is 77,316. However, the recovered people's ratio is higher than the ratio of death, but the increasing death ratio is not a good sign for the whole world. The plots of the deaths reported in the last ten days (March 29-April 6) from COVID-19 are presented in fig. 1.

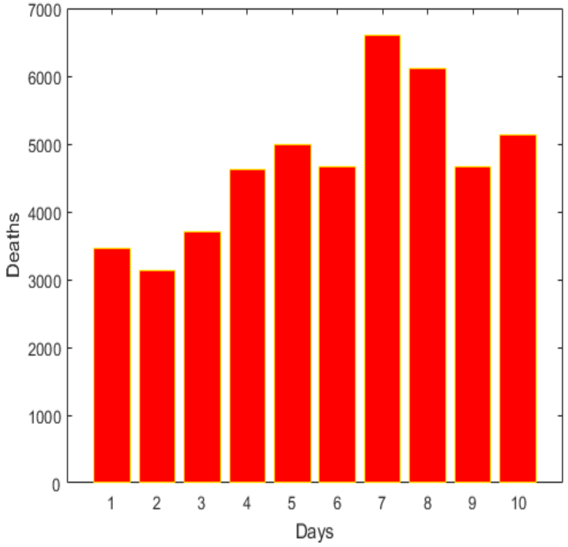

Fig. 1 The reported deaths for the last ten days through COVID-19

The present study aims to design a new quarantine SITR model based on the novel COVID-19. The solutions of this new quarantine SITR model have been presented using the numerical Runge-Kutta scheme. In addition, the brief detail of this model is also presented in the form of figures.

All the related studies reviewed during this attempt, whether to analyze to a greater or lesser extent, all have methodological limitations. These limitations prevent conclusions from being drawn concerning the effects of environmental and socioeconomic variables on COVID-19 outcomes. However, we dare to argue that the effects of these variables, if they exist, would be indirect, based on their relationship with social contact.

The remaining study of this model is presented as follows: Section 2 narrates the formulation of the quarantine SITR model based on the novel COVID-19 model. Section 3 represents the results and a detailed discussion of this new model. The last section indicates the conclusions of this designed study.

2. Formulation of the Quarantine SITR Model

This study aims to design a new quarantine SITR model using the novel COVID-19 based on the present information. The numerical results have been presented using the Runge-Kutta scheme [3-12]. The new quarantine SITR model is divided into susceptible (S) class, infected (I) class, treatment (T) class, and recovered (R) class. The susceptible (S) class is further divided into two subclasses, S_1 (t) and S_2 (t). The first and second subclass indicates individuals who are not infected with the COVID-19 and those who have old age or have serious diseases. I(t) is the class of individuals infected with COVID-19. The treatment T(t) class is further divided into two subclasses, T_1 (t) and T_2 (t). The subclass T_1 (t) is used for standard treatment, and the subclass T_2 (t) is the quarantine treatment. The fourth is the recovery R(t) class of those individuals that can recover from this dangerous disease at time t. The general form of the newly designed quarantine SITR model is written as follows:

Most of the styles are intuitive. However, there is a brief description below.

$$\begin{cases} S_1'(t) = B - \delta\beta\big(T_1(t) + T_2(t)\big) - \beta I(t)S_1(t) - \alpha S_1(t), S_1(0) \\ S_2'(t) = B - \delta\beta\big(T_1(t) + T_2(t)\big) + \beta I(t)S_2(t) + \alpha S_2(t), S_2(0) \\ I'(t) = -\mu I(t) + \beta\big(S_1(t) + S_2(t)\big)I(t) + \sigma I(t), I(0) = i_3, \\ T_1'(t) = \mu I(t) - \alpha T_1(t) - \rho T_1(t) + \varepsilon, T_1(0) = i_4, \\ T_2'(t) = \mu I(t) - \alpha T_2(t) + \xi, T_2(0) = i_5, \\ R'(t) = \rho\big(T_1(t) + T_2(t)\big) - \alpha R(t), R(0) = i_6. \end{cases} \tag{1}$$

The system given in equation (1) shows the quarantine SITR model. The parameters, along with their descriptions, are provided in Table 1, given as:

Table 1 Parameters along with the descriptions of the quarantine SITR model

Parameter	Description
$S_1(t)$	Not Infected individuals
$S_2(t)$	Not infected older people or having serious diseases
$I(t)$	Infected persons from the COVID-19
$R(t)$	Recovered persons from the COVID-19
$T_1(t)$	Normal treatment
$T_2(t)$	Quarantine treatment
δ	Reduce infection by treatment
β	Contact rate
B	Natural birth rate
μ	Recovery rate
α	Death rate
σ	Dry cough, fever, and tiredness rate
ξ	Stress rate
ρ	Infection rate
ε	Sleep factor
$i_n,\ n = 1, 2, \ldots, 6$	Initial conditions

The mathematical quarantine SITR model structure simplifies parameters, variables, and assumptions. Many numerically and analytical schemes have been presented to observe the mathematical form of infectious diseases. The study of the epidemic models and assessments of theoretical signs of progress are presented in [13-16]. Ogren and Martin [17] used the embedded Newton's approach to get the optimal control strategy in the biological SIR model. Goufo et al. [18] applied a fractional model of the SIR epidemic for the spatial spread of measles in people. Mickens [19] used the vaccination in the discrete-time system to spread periodic viruses. Furthermore, another epidemic system has also been discussed [20-22]. The current study is to solve model 1 using the Runge-Kutta numerical scheme by taking the best values of the parameters.

3. Solution of the Quarantine SITR Model

The detailed discussions for solving the quarantine SITR model based on the novel COVID-19 are provided in this section. The solution of the designed model is presented further in two types, and the numerical solutions have been plotted using the Runge-Kutta scheme. The different epidemic parameter values are given in Table 2, written as:

Table 2 State variables of the quarantine SITR model

Parameter class	Values (1)	Values (2)
B	0.6	0.85
β	0.4	0.6
α	0.1	0.05
μ	0.3	0.07
σ	0.05	0.08
δ	0.3	0.5
ρ	0.3	0.1
ε	0.05	0.25
ξ	0.07	0.3
i_1	0.3	0.45
i_2	0.4	0.35
i_3	0.5	0.25
i_4	0.6	0.15
i_5	0.7	0.1
i_6	0.8	0.3

In order to present the graph of susceptible (S) class, infected (I) class, treatment (T) class, and recovered

(R) class along with the two subclasses of susceptibility and treatment is provided in fig. 2 and 3. These figures are plotted using the suitable parameter class values given in Table 2. It is clear in fig. 2 that the S2(t) ratio is getting high with the number of days, which indicates that individuals who are older or have some serious diseases are increasing. The same results have been seen in Fig. 3.

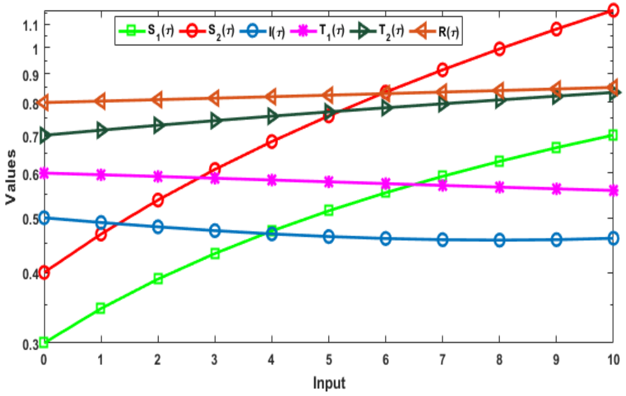

Fig. 2 The COVID-19 dynamics of the quarantine SITR model for first parameter class values of Table 2

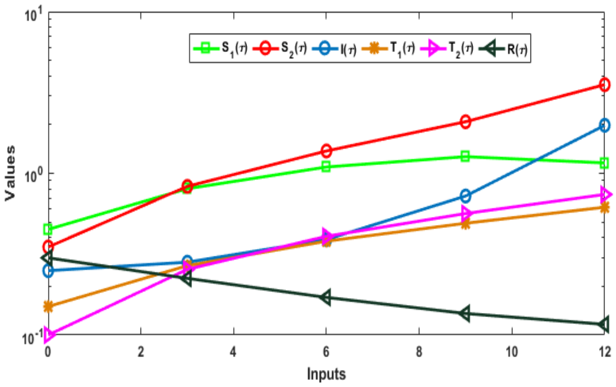

Fig. 3 The COVID-19 dynamics of the quarantine SITR model for second parameter class values in Table 2

4. Conclusion

The COVID-19 pandemic has viciously engulfed the entire world since January 2020, representing a crisis of an order unseen in the recent past. At the same time, the world has been scrambling to come to order and restore normalcy. So, different models and techniques were presented to accelerate the spread of these discussion themes. The present aim of this study is to introduce the Quarantine class in the nonlinear SITR model based on the COVID-19. The proposed model is classified into 4 classes named as susceptible (S) class, infected (I) class, treatment (T) class, and recovered (R) class at a time.

Moreover, the two classes, susceptible (S) and treatment (T), are further divided into two subclasses. The description of every class is briefly described by the values of the parameter figure plots. The presented model gives a brief sketch of quarantine class, which is essential to rescue the affected population through this worse pandemic. On the whole, the most fluent tool is the Runge-Kutta method was applied which provides the base work for the designed model. Among all other tools for successive iteration, the designed model SITR based on Ruge-Kutta is more efficient, reliable, and adequate because of its specialty and efficient role. It is concluded that the COVID-19 is spreading rapidly and speedy. Those individuals who are yet not affected by this disease are getting lesser in numbers, which is not a good sign for the whole world. The different values of the parameter show very good results based on the designed quarantine SITR model.

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