Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
A new study of unreported cases of 2019-nCOV epidemic outbreaks

Wei Gao\textsuperscript{a,}\textsuperscript{*}, P. Veeresha\textsuperscript{b}, Haci Mehmet Baskonus\textsuperscript{c}, D.G. Prakasha\textsuperscript{d}, Pushpendra Kumar\textsuperscript{e}

\textsuperscript{a}School of Information Science and Technology, Yunnan Normal University, Yunnan, China
\textsuperscript{b}Department of Mathematics, Karnatak University, Dharwad-580003, India
\textsuperscript{c}Department of Mathematics and Science Education, Faculty of Education, Harran University, Sanliurfa, Turkey
\textsuperscript{d}Department of Mathematics, Faculty of Science, DAVangere University, Shivaganganthri, Davangere 577007, India
\textsuperscript{e}Department of Mathematics and Statistics, School of Basic and Applied Sciences, Central University of Punjab, Bathinda, Punjab 151001, India

\textbf{A R T I C L E   I N F O}

Article history:
Received 6 April 2020
Revised 13 May 2020
Accepted 21 May 2020
Available online 8 June 2020

Keywords:
Coronavirus
Reported and unreported cases
Epidemic mathematical model
Caputo derivative, \(q\)-homotopy analysis transform method

\textbf{A B S T R A C T}

2019-nCOV epidemic is one of the greatest threats that the mortality faced since the World War-2 and most decisive global health calamity of the century. In this manuscript, we study the epidemic prophecy for the novel coronavirus (2019-nCOV) epidemic in Wuhan, China by using \(q\)-homotopy analysis transform method (\(q\)-HATM). We considered the reported case data to parameterize the model and to identify the number of unreported cases. A new analysis with the proposed epidemic 2019-nCOV model for unreported cases is effectuated. For the considered system exemplifying the model of coronavirus, the series solution is established within the frame of the Caputo derivative. The developed results are explained using figures which show the behaviour of the projected model. The results show that the used scheme is highly emphatic and easy to implementation for the system of nonlinear equations. Further, the present study can confirm the applicability and effect of fractional operators to real-world problems.

\(\text{© } 2020\text{ Elsevier Ltd. All rights reserved.}\)

1. Introduction

Besides the deadly infectious virus known as severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome Coronavirus (MERS-CoV), there is another one called novel coronavirus (2019-nCOV) \cite{1}. 2019-nCOV is more transmissible than the previous ones. The first outbreak of the 2019-NCOV has been observed in China in the city of Wuhan, in December 2019. The main source of this virus is not yet completely confirmed but the seafood market of Wuhan is considered as the main source of infection \cite{2}. Coronavirus is found in both sexes and most of all age groups and affecting more than 190 countries and territories around the world. Current reports acquaint that COVID-19 transmission may occur from an infectious individual, who is not yet symptomatic. It is recorded that appearance of the symptoms of this virus taking two to fourteen days.

From the date of its origin it exponentially growth in the mankind and infected more than 41, 78, 110 with 283,734 deaths on May 10 throughout the globe. Breathing difficulty, fatigue, fever, dry cough, tiredness, conjunctivitis, chest pain, loss of speech, diarrhoea and sore throat are the most serious symptoms in the infected peoples of COVID-19. Specifically, fatigue with 68.3\%, 64.4\% of taste and smell commotion, dry cough with 60.4\%, fever of about 55.5\%, the pain of muscle is about 44.6\%, 42.6\% of headache, breathing problem with 41.1\% and sore throat with 31.2\%, and others are the main available symptoms of COVID-19 in the general category \cite{3}. But, it varies from gender to gender and also with different age. The symptoms include breathing difficulties, coughing, and fever. This is also be noted that if the individuals are above 60 years old then this virus becomes more deadly and effects very fast \cite{4}. This virus is Coronavirus family and the Nidovirales order and enveloped positive-sense, non-segmented RNA viruses and widely distributed in mammals particularly, humans \cite{5}.

In order to overcome this challenge, every day numerous tests, analysis, examination, estimation and predictions are held via research. The antibody responses for the novel virus have been discussed by researchers in \cite{6} and presented some important and simulated results. Authors in \cite{7} presented the impact on the environment of glob and effects on society with COVID-19 and also discussed and illustrated the possible ways of controlling its effect on humankind. A model-based analysis has been exemplified by authors in \cite{8} and predictions and prevention approaches are presented and many researchers \cite{9}.

Nature is always provided with all essential needs for the leaving beings for systematic life. But, mankind is tried to overcome limitations raised by nature in order to prove he is best and first for the world and as its response we have the above. However, we have many tools in order to analyse and predict the behaviour of the models illustrating various phenomena including virus and

\* Corresponding author.
\textit{E-mail address:} gaowei@ynnu.edu.cn (W. Gao).

https://doi.org/10.1016/j.chaos.2020.109929
0960-0779/© 2020 Elsevier Ltd. All rights reserved.
its corresponding consequences. Particularly, researchers considered mathematics as a pivotal tool in order to model the evaluation of various phenomena. The concept of calculus with integral and differential operators is the most favourable and efficient weapon to examine and build models of epidemics and pandemics. In this connection, many researchers investigate various model exemplifying the evaluation, prediction and effects of 2019-nCoV on mortality. With the aid of dataset, the COVID-19 epidemic is analysed by researchers in [10] using ARIMA model, in [11] illustrated the effect of COVID-19 in China with undetected infections and cited some interesting results. Some researchers are mathematical models to illustrate the effect of coronavirus in country wise with the help of real data [12–14] and reference therein.

On other hand, many researchers pointed out some limitations about the study of the concept of calculus with integer order, specifically while analysing the phenomena associated to diffusion, long-range wave, hereditary properties, history-based phenomena and others. These consequences are very vital to understand the behaviour of the models which describes various phenomena. In this connection, many pioneers suggested the generalization of calculus with fractional order called fractional calculus (FC) to incorporate the above-mentioned phenomena [15–17]. There have been distinct definitions for differential and integrals with fractional calculus [16,17]. In this paper, we used the most familiar and highly employed operator called Caputo fractional operator. Recently, many researchers are hired theory and applications of FC in order to illustrate their viewpoints while analysing various problems. For instance, authors in [18] analysed Pine Wilt Disease model with convex rate using semi-analytical technique within the frame of fractional calculus, the harmonic oscillator is studies by researchers in [19] using fractional operator with position-dependent mass, pollution of lake model has been analysed and presented some simulating results by authors in [20], some interesting consequences of mathematical exemplifying human liver is illustrated in by authors in [21] using recently proposed fractional operator, and many other interesting phenomena by numerous researchers [22–28].

The aim of this paper is to clearly describe the reported and unreported cases by the help of Caputo derivative by analysing a time-fractional model and finding its solution by the q-homotopy analysis transform method. Since, for every differential system, we don’t have an exact or analytical solution, and hence we referred to semi-analytical or numerical schemes. There have numerous techniques in the literature. Most of them have their own limitations, for instance, accuracy, linearization, huge computation, perturbation, huge time of simplification, dissertation and many others. However, recently many researchers showed that homotopy analysis scheme with Laplace transform to overcome the above-mentioned limitations. The considered solution procedure is proposed by Singh et al. [29] with the aid of q-HAM and LT. Later, it has been hired by many researchers to find the solution for various classes of nonlinear differential equations describing various phenomena including fluid mechanics, optics, chaotic behaviour, human disease, biological models, economic growth, chemical and others [30–37], and also presented some interesting simulating consequences with the comparison of other traditional and modified techniques. Recently, it has been proved by many researchers, the considered method offers two parameters and which can assist us to converge our solution to an analytical solution with the minimum number of iterations and so on [33–84,12,43–63].

2. Preliminaries

Here, basic notations are recalled for the FC and Laplace transform.

**Definition 1.** The fractional Riemann-Liouville derivative of a function \( f(t) \) is defined as [15]

\[
\mathcal{D}_f^\alpha f(t) = \frac{1}{\Gamma(n-\alpha)} \int_0^t (t-\tau)^{n-\alpha-1} f(\tau) \, d\tau, \quad n-1 < \alpha \leq n.
\]

**Definition 2.** The Caputo fractional order derivative of \( f \in \mathbb{C}^1 \) is presented as follows [15–17]

\[
\mathcal{D}_f^\alpha f(t) = \int_0^t \frac{1}{\Gamma(n-\alpha)} (t-\tau)^{n-\alpha-1} f^{(n)}(\tau) \, d\tau, \quad n-1 < \alpha < n, n \in \mathbb{N}.
\]

**Definition 3.** Laplace transform (LT) of \( f(t) \) with respect to fractional Caputo derivative [15–17] is

\[
\mathcal{L}[\mathcal{D}_f^\alpha f(t)] = s^\alpha F(s) - \sum_{r=0}^{n-1} s^{\alpha-r-1} f^{(r)}(0^+), \quad (n-1 < \alpha \leq n),
\]

where \( F(s) \) is LT of \( f(t) \).

3. Model descriptions

In the present investigation, we consider the epidemic model studied by Liu et al. [39]. In [39], the authors presented and derived some interesting results for the projected model by comparison with some practical values and also cited interesting results. The considered model consists of four compartments with individuals of susceptible \( S(t) \), asymptomatic infectious \( I(t) \), reported symptomatic infectious \( R(t) \), unreported symptomatic infectious \( U(t) \). Now, the ordinary nonlinear differential system is considered as follows [39]

\[
\begin{align*}
\frac{dS(t)}{dt} &= -\rho S(t)[I(t) + U(t)], \\
\frac{dI(t)}{dt} &= \rho S(t)[I(t) + U(t)] - \beta I(t), \\
\frac{dR(t)}{dt} &= \beta I(t) - \mu R(t), \\
\frac{dU(t)}{dt} &= \beta I(t) - \mu U(t).
\end{align*}
\]

The considered model is generalised to fractional order with the aid of novel fractional operator called Caputo derivative. Now, the generalised system of the considered model defined in Eq. (4) is as follows

\[
\begin{align*}
\mathcal{D}_f^\alpha S(t) &= -\rho S(t)[I(t) + U(t)], \\
\mathcal{D}_f^\alpha I(t) &= \rho S(t)[I(t) + U(t)] - \beta I(t), \\
\mathcal{D}_f^\alpha R(t) &= \beta I(t) - \mu R(t), \\
\mathcal{D}_f^\alpha U(t) &= \beta I(t) - \mu U(t).
\end{align*}
\]

4. Fundamental solution procedure of q-HATM

In this segment, to illustrate the solution procedure of the proposed technique we consider fractional differential equation [29,30,40,41]

\[
\mathcal{D}_f^\alpha \psi(x,t) + \mathcal{R}\psi(x,t) + N\psi(x,t) = f(x,t), \quad n-1 < \alpha \leq n,
\]

with the initial condition

\[
\psi(x, 0) = \rho(x).
\]
where $D_x^q v(x, t)$ symbolise the Caputo derivative of $v(x, t)$. By applying LT on Eq. (6), one can get
\begin{equation}
L[v(x, t)] - \frac{\partial v(x, t)}{\partial t} + \frac{1}{s^q} [L[Rv(x, t)] + L[Nv(x, t)] - L[f(x, t)]] = 0.
\end{equation}

(8)

Then we define the nonlinear operator for corresponding real-valued function $\varphi(x, t; q)$
\begin{align*}
N[\varphi(x, t; q)] &= L[\varphi(x, t; q)] - \frac{\partial \varphi(x, t; q)}{\partial t} \\
&+ \frac{1}{s^q} [L[R\varphi(x, t; q)] + L[N\varphi(x, t; q)] - L[f(x, t)]]
\end{align*}

where $q \in [0, \frac{1}{2}]$. Now, the homotopy is defined as follows
\begin{equation}
(1 - q)N[\varphi(x, t; q)] - v_0(x, t) = hqN[\varphi(x, t; q)],
\end{equation}

(10)

where $L$ is signifying LT, $q \in [0, \frac{1}{2}]$ (n $\geq 1$) is the embedding parameter and $h \neq 0$ is an auxiliary parameter. For $q = 0$ and $q = \frac{1}{2}$, the results are given below hold true
\begin{align*}
\varphi(x, t; 0) &= v_0(x, t), \\
\varphi(x, t; \frac{1}{2}) &= v(x, t).
\end{align*}

(11)

Now, by intensifying $q$ from 0 to $\frac{1}{2}$, then $\varphi(x, t; q)$ varies from $v_0(x, t)$ to $v(x, t)$. By applying Taylor theorem near to $q$, we have
\begin{equation}
\varphi(x, t; q) = v_0(x, t) + \sum_{m=1}^{\infty} \frac{v_m(x, t)q^m}{m!},
\end{equation}

(12)

where
\begin{equation}
v_m(x, t) = \frac{1}{m!} \frac{\partial^m v(x, t; q)}{\partial q^m} \bigg|_{q=0}.
\end{equation}

(13)

On m-times differentiating Eq. (10) with $q$ and then multiply by $\frac{1}{m!}$ and later substituting $q = 0$, we have
\begin{equation}
L[v_m(x, t) - k_m v_{m-1}(x, t)] = h^m \varphi_m(\theta_{m-1}),
\end{equation}

(14)

where the vectors are defined as
\begin{equation}
v_m = \{v_0(x, t), v_1(x, t), \ldots, v_m(x, t)\}.
\end{equation}

(15)

On applying inverse LT to Eq. (14), it reduces to
\begin{equation}
v_m(x, t) = k_m v_{m-1}(x, t) + h^{-1}[\varphi_m(\theta_{m-1})],
\end{equation}

(16)

where
\begin{align*}
\varphi_m(\theta_{m-1}) &= L[v_{m-1}(x, t)] - \left(1 - \frac{k_m}{n}\right) \left(\frac{\partial v(x, t)}{\partial t} + \frac{1}{s^q} L[f(x, t)]\right) \\
&+ \frac{1}{s^q} [L[Rv_{m-1}] + H_{m-1}]
\end{align*}

and
\begin{equation}
k_m = \begin{cases} 0, & m \leq 1, \\ n, & m > 1. \end{cases}
\end{equation}

(17)

In Eq. (17), $H_m$ is homotopy polynomial and which is defined as
\begin{equation}
H_m = \frac{1}{m!} \left[\frac{\partial^m \varphi(x, t; q)}{\partial q^m}\right]_{q=0} \quad \text{and} \quad \varphi(x, t; q) = \varphi_0 + \varphi_1 + \varphi_2 + \ldots
\end{equation}

(19)

By the aid of Eqs. (16) and (17), one can get
\begin{align*}
v_m(x, t) &= (k_m + h)v_{m-1}(x, t) - \left(1 - \frac{k_m}{n}\right) \left(\frac{\partial v(x, t)}{\partial t} + \frac{1}{s^q} L[f(x, t)]\right) \\
&+ hL^{-1} \left[\frac{1}{s^q} L[Rv_{m-1}] + H_{m-1}\right].
\end{align*}

(20)

Then, the terms of $v_m(x, t)$ can be getting by the help of Eq. (20). The $q$-HATM series solution is defined below
\begin{equation}
v(x, t) = v_0(x, t) + \sum_{m=1}^{\infty} v_m(x, t).
\end{equation}

(21)

5. Solution for the projected model using $q$-HATM

Now, we consider the fractional-order system of equations illustrating the dynamics of the presented in Eq. (5)
\begin{align*}
D_t^q S(t) + \rho S(t)[I(t) + U(t)] &= 0, \\
D_t^q I(t) - \rho S(t)[I(t) + U(t)] + \beta I(t) &= 0, \\
D_t^q R(t) - \beta I(t) + \mu R(t) &= 0, \\
D_t^q U(t) - \beta S(t) + \mu U(t) &= 0,
\end{align*}

(22)

with initial conditions
\begin{align*}
S(0) &= S_0, & I(0) &= I_0, & R(0) &= R_0, & U(0) &= U_0.
\end{align*}

(23)

Now, applying LT on Eq. (22) and with the assist of Eq. (23), one can get
\begin{align*}
L[S(t)] - \frac{1}{s} (S_0) + \frac{1}{s^q} L[\rho S(t)I(t) + U(t)] &= 0, \\
L[I(t)] - \frac{1}{s} (I_0) - \frac{1}{s^q} L[\rho S(t)I(t) + U(t)] + \beta I(t) &= 0, \\
L[R(t)] - \frac{1}{s} (R_0) - \frac{1}{s^q} L[\beta I(t) + \mu R(t)] &= 0, \\
L[U(t)] - \frac{1}{s^q} L[\beta S(t) + \mu U(t)] &= 0.
\end{align*}

(24)

Now, the nonlinear operator is presented as
\begin{align*}
N^1[\varphi_1, \varphi_2, \varphi_3, \varphi_4] &= L[\varphi_1(t; q)] - \frac{1}{s} (S_0) \\
&+ \frac{1}{s^q} L[\rho \varphi_1(t; q)\varphi_2(t; q) + \varphi_4(t; q)], \\
N^2[\varphi_1, \varphi_2, \varphi_3, \varphi_4] &= L[\varphi_2(t; q)] - \frac{1}{s} (I_0) \\
&- \frac{1}{s^q} L[\rho \varphi_1(t; q)\varphi_3(t; q) + \varphi_4(t; q)] \\
&- (\rho + \varphi_2(t; q) + \beta \varphi_2(t; q)), \\
N^3[\varphi_1, \varphi_2, \varphi_3, \varphi_4] &= L[\varphi_3(t; q)] - \frac{1}{s} (R_0) \\
&- \frac{1}{s^q} L[\beta \varphi_3(t; q) + \mu \varphi_3(t; q)], \\
N^4[\varphi_1, \varphi_2, \varphi_3, \varphi_4] &= L[\varphi_4(t; q)] - \frac{1}{s} (U_0) \\
&- \frac{1}{s^q} L[\beta \varphi_2(t; q) + \mu \varphi_4(t; q)].
\end{align*}

(25)

By employing the projected scheme and for $H(t) = 1$, the $m$-th order deformation equation is presented as
\begin{align*}
L[S_m(t) - k_m S_{m-1}(t)] &= h_{1,m} S_{m-1} - I_{m-1} R_{m-1} - U_{m-1}, \\
L[I_m(t) - k_m I_{m-1}(t)] &= h_{2,m} S_{m-1} - I_{m-1} R_{m-1} - U_{m-1}, \\
L[R_m(t) - k_m R_{m-1}(t)] &= h_{3,m} S_{m-1} - I_{m-1} R_{m-1} - U_{m-1}, \\
L[U_m(t) - k_m U_{m-1}(t)] &= h_{4,m} S_{m-1} - I_{m-1} R_{m-1} - U_{m-1},
\end{align*}

(26)

where
Table 1
Parameters cited in Eq. (4) and their corresponding value [39].

| Parameter | Value |
|-----------|-------|
| $\mu$     | $4.48 \times 10^{-8}$ |
| $\alpha$  | $\frac{1}{2}$ |
| $\beta_1$ | $0.8 \times \mu$ |
| $\beta_2$ | $0.2 \times \mu$ |

\[ R_{1,m} \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \]

\[ = l[S_{m-1}(t)] - \left( 1 - \frac{k_m}{m} \right) \frac{1}{3}(S_0) + \frac{1}{2m}L \left\{ \sum_{i=0}^{m-1} S I_{m-1-i} - \sum_{i=0}^{m-1} S U_{m-1-i} \right\}, \]

\[ R_{2,m} \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \]

\[ = l[I_{m-1}(t)] - \left( 1 - \frac{k_m}{m} \right) \frac{1}{3}(I_0) - \frac{1}{2m}L[I_0(1)] + \beta I_{m-1}(t) \frac{1}{2m}L[I_0(1)] + \mu \beta I_{m-1}(t) \frac{1}{2m}L[I_0(1)]. \]

\[ R_{3,m} \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \]

\[ = l[R_{m-1}(t)] - \left( 1 - \frac{k_m}{m} \right) \frac{1}{3}(R_0) - \frac{1}{2m}L[\beta I_{m-1}(t) + \mu R_{m-1}(t)]. \]

\[ R_{4,m} \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \]

\[ = l[U_{m-1}(t)] - \left( 1 - \frac{k_m}{m} \right) \frac{1}{3}(U_0) - \frac{1}{2m}L[\beta_2 I_{m-1}(t) + \mu U_{m-1}(t)]. \] (27)

Eq. (26) simplifies by the help of inverse LT as follows

\[ S_m(t) = k_m S_{m-1}(t) + h L^{-1} \left\{ 1_m \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \right\}, \]

\[ I_m(t) = k_m I_{m-1}(t) + h L^{-1} \left\{ 2_m \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \right\}, \]

\[ R_m(t) = k_m R_{m-1}(t) + h L^{-1} \left\{ 3_m \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \right\}, \]

\[ U_m(t) = k_m U_{m-1}(t) + h L^{-1} \left\{ 4_m \left[ \hat{S}_{m-1}, \hat{I}_{m-1}, \hat{R}_{m-1}, \hat{U}_{m-1} \right] \right\}. \] (28)

On simplifying the above system and with the assist of initial values, we obtained the required series solution. Then for Eq. (22), the $q$-HATM series solution is defined as

\[ S(t) = S_0(t) + \sum_{m=1}^{\infty} S_m(t) \left( \frac{1}{q} \right)^m, \]

\[ I(t) = I_0(t) + \sum_{m=1}^{\infty} I_m(t) \left( \frac{1}{q} \right)^m, \]

\[ R(t) = R_0(t) + \sum_{m=1}^{\infty} R_m(t) \left( \frac{1}{q} \right)^m, \]

\[ U(t) = U_0(t) + \sum_{m=1}^{\infty} U_m(t) \left( \frac{1}{q} \right)^m. \] (29)

5. Results and discussion

In this paper, we consider the initial conditions for the projected epidemic model as $S(0) = S_0 = 11.081 \times 10^6$, $I(0) = I_0 = 3.62$, $R(0) = R_0 = 0$ and $U(0) = U_0 = 4.13$. We evaluate up to a third-order series solution to capture the behaviour for the model. Fig. 1 exemplifies the behaviour of achieved results by projected solution procedure for $S(t)$, $I(t)$, $R(t)$ and $U(t)$ for different fractional order ($\alpha$) with respect to time ($t$) and we consider values of all the parameters with the help of Table 1. The considered system contains the four compartments and which exemplifies the current situation in the globe and also these types of models can aid to examine the nature and predict the exponential growth of the great-
est threat of present days. We can observe from the plots that susceptible $S(t)$, asymptomatic infectious $I(t)$, reported symptomatic $R(t)$ and unreported symptomatic infectious $U(t)$ are effectively depends on the time and order of the system. Further, we capture corresponding behaviour with the values of $\alpha = 0.6$, $0.7$, $0.8$, $0.9$ and for classical order ($\alpha = 1$) and we can see that the projected model has to simulate behaviour with respect to parameters cited in Table 1 and fractional order. The behaviour cited shows the ability and efficiency of the considered solution procedure and from the cited figures it is clear that the projected model extremely depends on the order and offers more degree of flexibility. Moreover, the considered fractional operator provides more interesting consequences to examine and predict the future of the considered model. The epidemic models are highly dependent on hereditary properties and hence, the present investigation may help to understand the deadly virus.

6. Conclusion

In the neoteric decade, so many deadly diseases have apparent their existence in many countries around the world. We studied a time-fractional model of 2019–nCoV with the successful application of $q$-HATM. For the given model series solutions are obtained. We achieved these results by using the fractional derivative called Caputo derivative. Our results are helpful to make an idea of un-reported cases in Wuhan, China of this virus. The behaviour of the achieved third-order solution has been exemplified with the aid of plots and which demonstrate the effect and essence generalizing the integer order system into an arbitrary order system with the specific theory of fractional calculus. The projected scheme is strong and highly credible in finding the solution to fractional models of biological, physical and medical importance. For the solution of the epidemic model, we presented various graphical results at the different values of $\alpha$. The present study exemplifies the applications of the projected method and considered fractional operator while analysing real word problems and understanding as well as predicting the corresponding consequences.

Credit author statement

P. Veeresha and D.G. Prakasha combined of the presented idea. H.M. Baskonus, W. Gao and P. Kumar have analyzed the results. All authors discussed the results and contributed to the final manuscript.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Reference

[1] Jang S, Xia S, Ying T, et al. A novel coronavirus (2019-nCoV) causing pneumonia-associated respiratory syndrome. Cell Mol Immunol 2020;17(554). DOI:10.1007/s12317-020-0219-6.
[2] Lin Q, Zhao S, et al. A conceptual model for the coronavirus disease 2019 (COVID-19) outbreak in Wuhan, China with individual reaction and governmental action. Int J Infect Dis 2020;93:211–16.
[3] Medical News Today. [https://www.medicalnewstoday.com/articles/Coronavirus-Early-Symptoms#Children] May (2020).
[4] New England Journal of Medicine. Letter to the Editor. Available online: https://www.nejm.org/doi/full/10.1056/NEJMe2001468 (accessed on 30 January 2020). 2020.
[5] Huang C, Wang Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395(10223):497–506.
[6] Long Q, Liu B, Deng H, et al. Antibody responses to SARS-Cov-2 in patients with COVID-19. Nat Med 2020. DOI:10.1038/s41591-020-0987-1.
[7] Chakraborty I, Maity P. The COVID-19 outbreak: migration, effects on society, global environment and prevention. Sci Total Environ 2020;728. DOI:10.1016/j.scitotenv.2020.136882.
[8] S.S. Nadlim, I. Ghosh, J. Chattopadhay, Short-term predictions and prevention strategies for COVID-2019: a model based study. Preprint, arXiv:2003.01851 [q-bio.PE] (2020), 1–36.
[9] Veeresha P, Prakasha DG, Malagi NS, Baskonus HM. New dynamical behaviour of the coronavirus (COVID-19) infection system with nonlocal operator from reservoirs to people. Res Sq 2020. DOI:10.21203/rs.3.rs-19500/v1.
[10] Benvenuto D, Giovanetti M, et al. Application of the ARIMA model on the COVID-19 epidemic dataset. Data Brief 2020;29. DOI:10.1016/j.dib.2020.105340.
[11] Ivorra B, Fernandez MR, Vela-Perez M, Ramos AM. Mathematical modeling of the spread of the coronavirus disease 2019 (COVID-19) taking into account the undiagnosed infections. The case of China. Comm Nonlinear Sci Numer Simul 2020;105303.
[12] Nishiura H, Jung S, et al. The extent of transmission of novel coronavirus in Wuhan, China. J Clin Med 2020;9(330). DOI:10.3390/ijerph90203310.
[13] Shukla AS, Shaikh HH, Nisar K. A mathematical fractional-order model of COVID-19 with fractional derivative: a dynamical study from the transmission. Chaos Solitons Fractals 2020;132. DOI:10.1016/j.chaos.2020.109754.
[14] Baleanu D, Jajarmi A, Hajishalimi A, Asad JH. The fractional features of a harmonic oscillator with position-dependent mass. Commun Theor Phys 2020;72. DOI:10.1088/1674-1137/ab7700.
[15] Prakash DG, Veeresha P. Analysis of Lakes pollution model with Mittag-Leffler kernel. J Eng Sci Technol 2020;1:13–13. DOI:10.37460/jest.2020.01104.
[16] Baleanu D, Jajarmi A, Mohammadi H, Rezapour S. A new study on the mathematical modeling of human liver with Caputo-Fabrizio fractional derivative. Chaos Solitons Fractals 2020;134. DOI:10.1016/j.chaos.2020.109705.
[17] Veeresha P, Prakash DG, Kumar D, Baleanu D, Singh J. An efficient computational technique for fractional order model of generalized homogeneous coupled Korteweg–de Vries and coupled modified Korteweg–de Vries equations. J Comput Nonlinear Dyn 2020;15(7). DOI:10.1115/1.4046898.
[18] Jajarmi A, Yufus A, Baleanu D, Inc M. A new fractional HRSV model and its optimal control: a non-singular operator approach. Phys A 2020;547. DOI:10.1016/j.physa.2019.123860.
[19] Yildiz TA, Jajarmi A, Yildiz B, Baleanu D. New aspects of time fractional optimal control problems within operators with nonsingular kernel. Discrete Cont Dyn Syst Ser S 2020;13(3):407–28.
[20] Belmor S, Ravichandran C, Jarad F. Nonlinear generalized fractional differential equations with generalized fractional integral conditions. J Taibah Univ Sci 2020;14(1):114–23.
[21] Jajarmi A, Baleanu D, Sajjadi SS, Asad JH. A new feature of the fractional Euler-Lagrange equations for a coupled oscillator using a non-singular operator approach. Front Phys 2019;26. DOI:10.3389/fphy.2019.00196.
[22] Gao W, Veeresha P, et al. Iterative method applied to the fractional nonlinear systems arising in thermoelasticity with Mittag-Leffler kernel. Fractals 2020. DOI:10.1142/S0218348X2040040X.
[23] Alqoudah MA, Ravichandran C, Abdeljawid T, Valliammal N. New results on Caputo fractional-order neutral differential inclusions without compactness. Adv Differ Equ 2019;528. DOI:10.1186/s13662-019-2455-7.
[24] Singh J, Kumar D, Sworoop R. Numerical solution of time- and space-fractional coupled Burgers’ equations via homotopy algorithm. Alexandria Eng J 2020;59(3):575–83.
[25] Veeresha P, Prakash DG, Kumar D. An efficient technique for nonlinear time-fractional Klein-Fock-Gordon equation. Appl Math Comput 2020;364:1–15. DOI:10.1016/j.amc.2019.124637.
[26] Srivastava HM, Kumar D, Singh J. An efficient analytical technique for fractional model of vibration equation. Appl Math Model 2017;45:192–204.
[27] Prakash A, Prakash DG, Veeresha P. A reliable algorithm for time-fractional Navier-Stokes equations via Laplace transform. Nonlinear Eng 2019;8(1):695–701.
[28] Gao W, Veeresha P, Prakash DG, Baskonus HM, Yel G. A powerful approach for fractional Drinfeld–Sokolov–Wilson equation with Mittag-Leffler law. Alexandria Eng J 2019;58:1301–11.
[29] Veeresha P, Prakash DG, Kumar S. A fractional model for propagation of classical optical solitons by using non-singular derivative. Math Methods Appl Sci 2020. DOI:10.1002/mma.6335.
[30] Prakash DG, Veeresha P, Singh J. Fractional approach for equation describing the water transport in unsaturated porous medium with Mittag-Leffler kernel. Front Phys 2019;7(93). DOI:10.3389/fphy.2019.00193.
[31] Kumar D, Agarwal RP, Singh J. A modified numerical scheme and convergence analysis for fractional model of Liouard’s equation. J Comput Appl Math 2018;339:405–13.
[32] Gao W, Veeresha P, Prakash DG, Baskonus HM, Yel G. New approach for the model describing the deadly disease in pregnant women using Mittag-Leffler function. Chaos Solitons Fractals 2020;134. DOI:10.1016/j.chaos.2019.109696.
[38] Veeresha P, Prakash DG, Baskonus HM. An efficient technique for a fractional-order system of equations describing the unsteady flow of a polytropic gas. Pramana J Phys 2019;93(7):10.1007/s12043-019-1829-9.

[39] Liu Z, Magal P, Seydi O, Webb G. Understanding unreported cases in the COVID-19 epidemic outbreak in Wuhan, China, and the importance of major public health interventions. Biology (Basel) 2020;9(50). doi:10.3390/biology9303050.

[40] Arfaa AAM, Hagag AMS. Q-homotopy transform method applied to fractional Kundu–Eckhaus equation and fractional massive Thirring model arising in quantum field theory. Asian-Eur J Math 2019;12(03).

[41] Veeresha P, Prakash DG, Baleanu D. Analysis of fractional Swift–Hohenberg equation using a novel computational technique. Math Methods Appl Sci 2020;43(4):1970–87.

[42] Cattani C. A review on harmonic wavelets and their fractional extension. J Adv Eng Comput 2018;2(4):224–38.

[43] Yokus A, Gulbahar S. Numerical Solutions with linearization techniques of the fractional Harry dyne equation. Appl Math Nonlinear Sci 2019;4(1):35–42.

[44] Cattani C, Ruschchitskii YY. Cubically nonlinear elastic waves: wave equations and methods of analysis. Int Appl Mech 2003;39:1115–45.

[45] Al-Ghafri KS, Rezazadeh H. Solutions and other solutions of (3 + 1)-dimensional space-time fractional modified KdV–Zakharov–Kuznetsov equation. Appl Math Nonlinear Sci 2019;4(2):289–304.

[46] Cattani C, Pierro G. On the fractal geometry of DNA by the binary image analysis. Bull Math Biol 2013;75(9):1544–70.

[47] Brzeziński DW. Review of numerical methods for NumLPT with computational accuracy assessment for fractional calculus. Appl Math Nonlinear Sci 2018;3(2):487–502.

[48] Cattani C. Harmonic wavelet solutions of the Schrodinger equation. Int J Fluid Mech Res 2003;30(5):463–72.

[49] Yang XJ, Baleanu D, Lazar eviction MP, Cajić MS. Fractal boundary value problems for integral and differential equations with local fractional operators. Therm Sci 2015;19(3):950–66.

[50] Yang XJ. A new technology for solving diffusion and heat equations. Therm Sci 2017;21(1 Part A):133–40.

[51] Atangana A. Fractional discretization: the African’s tortoise walk. Chaos Solitons Fractals 2020;130:109399.

[52] Khan MA, Hammouch Z, Baleanu D. Modeling the dynamics of hepatitis E via the Caputo–Fabrizio derivative. Math Model Nat Phenom 2019;14(3):311.

[53] Owolabi KM, Hammouch Z. Mathematical modeling and analysis of twovariable system with noninteger-order derivative. Chaos 2019;29(1):013145.

[54] Atangana A, Hammouch Z. Fractional calculus with power law: the cradle of our ancestors. Eur Phys J Plus 2019;134(9):429.

[55] Jothimani K, Kaliraj K, Hammouch Z, Ravichandran C. New results on controllability in the framework of fractional integro-differential equations with non-dense domain. Eur Phys J Plus 2019;134(9):441.

[56] Logeswari K, Ravichandran C. A new exploration on existence of fractional neutral integro-differential equations in the concept of Atangana–Baleanu derivative. Phys A 2020;554:123454. doi:10.1016/j.physa.2019.123454.

[57] Panda SK, Abdeljawad T, Ravichandran C. A complex valued approach to the solutions of Riemann–Liouville integral, Atangana–Baleanu integral operator and non-linear Telegraph equation via fixed point method. Chaos Solitons Fractals 2020;130:109439.

[58] Atangana A, Baleanu D. New fractional derivatives with nonlocal and non-singular kernel theory and application to heat transfer model. Therm Sci 2016;20:763–9.

[59] Cao W, Yel G, Baskonus HM, Cattani C. Complex Solitons in the Conformable (2+1)-dimensional Ablowitz-Kaup-Newell-Segur Equation. Aims Math 2020;5(1):507–21.

[60] Kumar S, Kumar A, Momani S, Alkhaffafa M, Nisar KS. Numerical solutions of non-linear fractional model arising in the appearance of the strip patterns in two-dimensional systems. Adv Differ Equ 2019:2019:413.

[61] Singh J, Kumar D, Hammouch Z, Atangana A. A fractional epidemiological model for computer viruses pertaining to a new fractional derivative. Appl Math Comput 2018;316:504–15.

[62] Kumar S, Nisar KS, Kumar R, Cattani C, Samet B. A new Rabotnov fractional-exponential function based fractional derivative for diffusion equation under external force. Math Methods Appl Sci 2020. doi:10.1002/mma.6258.

[63] Cao W, Veeresha P, Prakash DG, Baskonus HM. Novel dynamical structures of 2019-nCoV with nonlocal operator via powerful computational technique. Biology (Basel) 2020;9(5):107. doi:10.3390/biology9050107.