



A computational supervised neural network procedure for the fractional SIQ mathematical model

Kanit Mukdasai¹, Zulqurnain Sabir^{2,8}, Muhammad Asif Zahoor Raja³, Peerapongpat Singkibud^{4,a}, R. Sadat⁵, and Mohamed R. Ali^{6,7,b} 

¹ Department of Mathematics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand

² Department of Mathematics and Statistics, Hazara University, Mansehra, Pakistan

³ Future Technology Research Center, National Yunlin University of Science and Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, ROC

⁴ Department of Applied Mathematics and Statistics, Faculty of Science and Liberal Arts, Rajamangala University of Technology Isan, Nakhon Ratchasima 30000, Thailand

⁵ Department of Mathematics, Faculty of Engineering, Zagazig University, Zagazig, Egypt

⁶ Faculty of Engineering and Technology, Future University in Egypt, New Cairo 11835, Egypt

⁷ Basic Engineering Science Department, Benha Faculty of Engineering, Benha University, Benha, Egypt

⁸ Department of Computer Science and Mathematics, Lebanese American University, Beirut, Lebanon

Received 31 August 2022 / Accepted 28 November 2022 / Published online 4 January 2023

© The Author(s), under exclusive licence to EDP Sciences, Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract The purpose of the current work is to provide the numerical solutions of the fractional mathematical system of the susceptible, infected and quarantine (SIQ) system based on the lockdown effects of the coronavirus disease. These investigations provide more accurateness by using the fractional SIQ system. The investigations based on the nonlinear, integer and mathematical form of the SIQ model together with the effects of lockdown are also presented in this work. The impact of the lockdown is classified into the susceptible/infection/quarantine categories, which is based on the system of differential models. The fractional study is provided to find the accurate as well as realistic solutions of the SIQ model using the artificial intelligence (AI) performances along with the scale conjugate gradient (SCG) design, i.e., AI-SCG. The fractional-order derivatives have been used to solve three different cases of the nonlinear SIQ differential model. The statics to perform the numerical results of the fractional SIQ dynamical system are 7% for validation, 82% for training and 11% for testing. To observe the exactness of the AI-SCG procedure, the comparison of the numerical attained performances of the results is presented with the reference Adam solutions. For the validation, authentication, aptitude, consistency and validity of the AI-SCG solver, the computing numerical results have been provided based on the error histograms, state transition measures, correlation/regression values and mean square error.

1 Introduction

The human faced various troubles based on different viruses and diseases all the time. Some common viruses/diseases that are dangerous and troublesome for the humanity are Ebola, HIV and dengue, and most recent disease is coronavirus [1–3]. The dangerous coronavirus is communicated disease that has an effective part in the lives of the humans since 2020. It seriously affected the industrial zones, economic factors, sports activities, social actions, education fields

and other events [4, 5]. This virus is harmful, spreading rapidly with the huge casualties occurred in quick time. The effective coronavirus spreading role is due to transportations or travel of people through the flawed countries of various sectors [6, 7]. The procedure of the vaccination has been started that is helpful to control this virus. The coronavirus changed the human's life and the basic reason of the spreading of this disease is the migration of the individual from one to another place; however, few more reasons and symptoms have also been reported [8].

There have been several schemes that have been applied to present the mathematical formulations based on the coronavirus together with various topographies. Benvenuto et al. [9] executed the nonlinear ARIMA

^a e-mail: peerapongpat.si@rmuti.ac.th (corresponding author)

^b e-mail: mohamed.reda@bhit.edu.eg

model based on the coronavirus. Rhodes et al. [10] studied the communal sufferings-based coronavirus using the mathematical ODEs. Mustafa et al. [11] designed a mathematical formulation to analyze and forecast the transmission of coronavirus. Nesteruk [12] evaluated the dynamical form of the coronavirus in Ukraine based on the double set of data. Sivakumar [13] discussed the predictive measures to control the pandemic coronavirus in the region of India. Thompson [14] investigated the epidemiological model by using the momentous apparatus based on the coronavirus interventions. Libotte [15] designed an administration strategy using the vaccination process of the coronavirus. Gumel et al. [16] presented a mathematical coronavirus disease nonlinear system. Sadiq et al. [17] examined the of nano-material impacts to control the coronavirus. Ortenzi et al. [18] implemented an investigation using the trans-disciplinary discipline for this disease in Italy. Moore et al. [19] investigated a nonlinear system of coronavirus to examine the impacts of the vaccination along with the non-pharmaceutical interference. Sánchez et al. [20] proposed a SITR coronavirus mathematical model that is based on susceptible/infected/treatment/recovered system. Sabir et al. [21] designed the stochastic computing numerical procedure using the coronavirus SITR system. Umar et al. [22] provided the theoretical presentations to present the dynamical structure of the coronavirus. Chen et al. [23] show the effects of social distancing using the nonlinear form based on the coronavirus dynamics. Anirudh [24] investigated the dynamical structure of the transmission prediction of the coronavirus. Zhang et al. [25] stated the coronavirus studies using the performances of the perturbation stochastic factor.

The current investigations present the fractional derivative investigation based on the susceptibility/infected/quarantine, i.e., SIQ system based on the lockdown impacts of the coronavirus using the artificial intelligence (AI) performances along with the scale conjugate gradient (SCG) design, i.e., AI-SCG. The stochastic solvers have been used in the variety of applications in recent years [26–28]. Few of them are the singular model of third kind [29], nonlinear functional differential model [30] and singular kinds of fractional systems [31, 32]. However, these intelligent computing frameworks have yet to implement on fractional SIQ system considering the lockdown impacts on spread of coronavirus. Authors are motivated to investigate/explore in AI-SCG algorithms for fractional SIQ systems for the first time as per our literature review. The novel features of the AI-SCG scheme for the SIQ differential model are given as:

- A fractional SIQ system of coronavirus with the impact of lockdown is numerically studied.
- The stochastic computing procedure-based AI-SCG scheme has not been implemented before for solving the fractional SIQ nonlinear mathematical system.
- Three fractional-order variations of the fractional SIQ coronavirus system have been numerical discussed,

which validate the trustworthiness of the AI-SCG scheme.

- The competency of the computing stochastic AI-SCG scheme is observed by using the comparative performances of the achieved and Adam results.
- The accuracy/correctness and precision of the AI-SCG solver is observed based on the performances of the absolute error (AE), which is obtained in good order for solving the model.
- The error histograms (EHs) performances, state transitions (STs) measures, correlation/regression values and mean square error (MSE) approve the reliability of the AI-SCG procedure for the fractional SIQ nonlinear mathematical system.

The other sections of this paper are presented as: The construction of the fractional SIQ system is shown in 2nd Sect. The computing AI-SCG process is studied in 3rd Sect. The numerical results based on the fractional SIQ system are reported in 4th Sect. In the final section, concluding remarks of this study are presented.

2 System model: fractional SIQ nonlinear model

The current section presents the effects of the lockdown in the protective analysis of the SIQ system. The impact of the lockdown is classified into the susceptible/infections/quarantine categories, which is based on the system of differential models. The mathematical nonlinear SIQ system along with the initial conditions (ICs) is given as [33]:

$$\begin{cases} \frac{dS(v)}{dv} = (1 - \theta)m + a - \mu S(v) - \frac{\beta S(v)I(v)}{\alpha + \eta I(v)}, & S_0 = l_1, \\ \frac{dI(v)}{dv} = \frac{\beta(1-k)S(v)I(v)}{\eta I(v) + \alpha} + \theta m - (\delta_1 + \alpha_1 + \sigma + \mu)I(v), & I_0 = l_2, \\ \frac{dQ(v)}{dv} = \frac{k\beta I(v)S(v)}{\eta I(v) + \alpha} + \sigma I(v) - (\mu + \alpha_2 + \delta_2)Q(v), & Q_0 = l_3. \end{cases} \quad (1)$$

The exhaustive/necessary descriptions of terms/variables/parameters of the mathematical SIQ nonlinear system are presented in Table 1. Furthermore, the appropriate values of terms/variables/parameters have been selected as shown/reported in [33] together with the theoretical descriptions of the optimal control for necessary description global/local stabilities approaches.

The present work shows the computing numerical performance of the fractional SIQ nonlinear system-based lockdown effects of coronavirus by using the artificial intelligence (AI) performances along with the SCG-based neural networks design. The modified form

Table 1 Comprehensive descriptions of each class of the nonlinear SIQ mathematical system

Parameters	Particulars
α	Half capacity constant
a	Employment rate
η	Positive value
μ	Natural death ratio
β	Transmission rate of infection
m	Migrants number
δ_1	Infective population recovery
σ	0.6 per day
θ	Infected rate of migrants
k	Contact outlining rate
α_1	Disease-associated infective death rate of population
α_2	Disease-related population of quarantine with death ratio
δ_2	Recovered rate-based quarantined population
l_{-1}, l_{-2} and l_{-3}	ICs

of the model (1) is presented as:

$$\left\{ \begin{array}{l} \frac{d^\eta S(v)}{dv^\eta} = (1 - \theta)m + a - \mu S(v) \\ \quad - \frac{\beta S(v)I(v)}{\alpha + \eta I(v)}, \quad S_0 = l_1, \\ \frac{d^\eta I(v)}{dv^\eta} = \frac{\beta(1-k)S(v)I(v)}{\eta I(v) + \alpha} + \theta m \\ \quad - (\delta_1 + \alpha_1 + \sigma + \mu)I(v), \quad I_0 = l_2, \\ \frac{d^\eta Q(v)}{dv^\eta} = \frac{k\beta I(v)S(v)}{\eta I(v) + \alpha} \\ \quad + \sigma I(v) - (\mu + \alpha_2 + \delta_2)Q(v), \quad Q_0 = l_3. \end{array} \right. \quad (2)$$

where η represents the fraction0order Caputo derivative form of the SIQ nonlinear system. The values of the fractional derivative have been applied in the interval $[0, 1]$ to present the conduct of the dynamical SIQ nonlinear model.

The advantages of the fractional SIQ model presented in system (2) are incorporated to signify/observe the minute particulars (superfast/ superslow transients/evolutions) that are not easy to handle by using the classical integer order counterparts as presented in the system (1). However, inherent complexity of the fractional SIQ model in (2) is a limitation of the presented study due to availability of relatively few numerical and analytical procedures for solving fractional-order systems as portrayed in (2). Therefore, the aim of the presented study is to utilize the knacks of artificial intelligence performances along with the scale conjugate gradient design, i.e., AI-SCG, to analyze the dynamics of fractional-order system represented in set of Eq. (2).

3 Methodology: proposed AI-SCG procedure

This section shows the AI-SCG structure for the fractional SIQ dynamical system. The procedure is defined by using the important AI-SCG performances along with the execution measures using the AI-SCG scheme for solving the SIQ dynamical model. The designed AI-SCG scheme is implemented with the similar study as presented in [34, 35].

The procedure based on the optimization of the multilayers based on the stochastic numerical AI-SCG is presented in Fig. 1. The neuron structure-based single layer is presented in Fig. 2. The regression-based knacks of AI-SCG-based supervised neural networks are incorporated to study the dynamics of fractional SIQ system while reference dataset for the implementation of the regressive networks is formulated using Adams numerical procedures for the solution of fractional differential equations [36–38]. The statics to perform the numerical results of the fractional SIQ dynamical system are 7% for validation, 82% for training and 11% for testing.

4 Numerical results based on AI-SCG neural networks with discussion

The current section presents the numerical computing performances of three variations based on the fractional-order derivatives of the SIQ system by applying the AI- SCG-based neural networks. The three cases of fractional SIQ systems are formulated by taking the values of terms/variables/parameters as shown/reported in [33] for not only in-depth analysis of dynamic of the model but also to check the accuracy, robustness, stability and convergence of the proposed AI-SCG neural networks. The mathematical description of these three cases are given as follows:

Case 1: Consider $\eta = 0.5, \beta = 2.1, \alpha = 5, a = 2.6, \sigma = 0.59, \alpha_1 = 1.78, \eta = 1, \delta_1 = 0.4, \alpha_2 = 1.78, \mu = 5.2, \delta_2 = 0.4, k = 0.1, \theta = 0.9, m = 14, l_1 = 1.32, l_2 = 2.29$ and $l_3 = 3.5$ is given as:

$$\left\{ \begin{array}{l} \frac{d^{0.5} S(v)}{dv^{0.5}} = 4 - 5.2S(v) \\ \quad - \frac{2.1S(v)I(v)}{5+I(v)}, \quad S(0) = 1.32, \\ \frac{d^{0.5} I(v)}{dv^{0.5}} = 12.6 - 7.97I(v) \\ \quad + \frac{1.89I(v)S(v)}{I(v)+5}, \quad I(0) = 2.29, \\ \frac{d^{0.5} Q(v)}{dv^{0.5}} = 0.59I(v) \\ \quad + \frac{0.21S(v)I(v)}{5+I(v)} - 7.38Q(v), \quad Q(0) = 3.5. \end{array} \right. \quad (3)$$

Case 2: Consider $\eta = 0.5, \beta = 2.1, \alpha = 5, a = 2.6, \sigma = 0.59, \alpha_1 = 1.78, \eta = 1, \delta_1 = 0.4, \alpha_2 = 1.78, \mu = 5.2, \delta_2 = 0.4, k = 0.1, \theta = 0.9, m = 14, l_1 = 1.32,$

1. Problem: Fractional order SIQ model

Intelligent computational structure

A structure of the multi-layer programming through the proposed SCGNNs for the fractional SIQ mathematical coronavirus system

$$\begin{cases} \frac{d^\eta S(v)}{dv^\eta} = (1-\theta)m + a - \mu S(v) - \frac{\beta S(v)I(v)}{\alpha + \eta I(v)}, & S_0 = I_1, \\ \frac{d^\eta I(v)}{dv^\eta} = \frac{\beta(1-k)S(v)I(v)}{\eta I(v) + \alpha} + \theta m - (\delta_1 + \alpha_1 + \sigma + \mu)I(v), & I_0 = I_2, \\ \frac{d^\eta Q(v)}{dv^\eta} = \frac{k\beta I(v)S(v)}{\eta I(v) + \alpha} + \sigma I(v) - (\mu + \alpha_2 + \delta_2)Q(v), & Q_0 = I_3. \end{cases}$$

Mathematical System

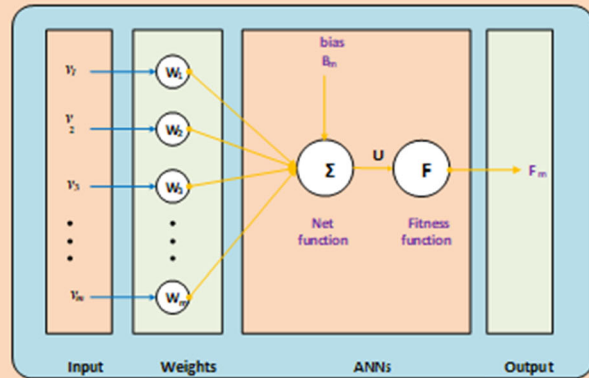
2. Methodology: SCGNNs

Reference results

Designed dataset using the numerical computing structure for the fractional SIQ mathematical coronavirus system

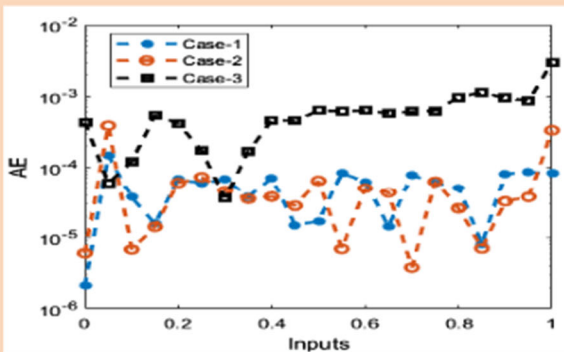
Obtained outputs

Simulate the proposed SCGNNs procedure based reference statics to get the estimated outputs for the fractional SIQ mathematical coronavirus system

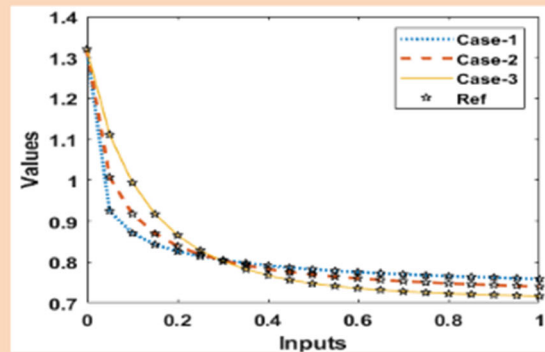


A single neuron network

3. Results with analysis



AE



Results

Designed SCGNNs procedure based fitness performances, STs values, EHs measures, regression analysis and MSE for the model

Fig. 1 Workflow illustrations-based AI-SCG-based neural networks for the fractional SIQ system

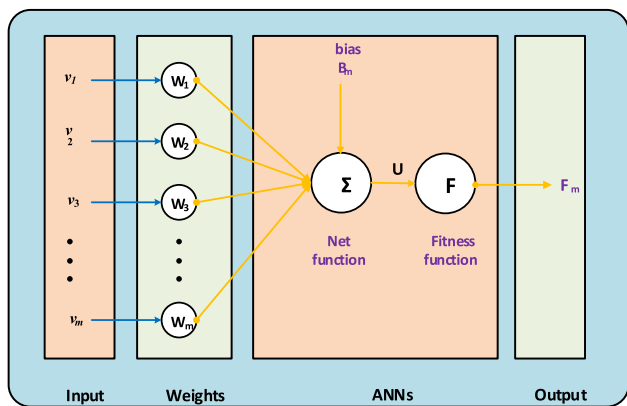


Fig. 2 A single-layered neuron structure

$l_2 = 2.29$ and $l_3 = 3.5$ is shown as:

$$\left\{ \begin{array}{l} \frac{d^{0.7}S(v)}{dv^{0.7}} = 4 - 5.2S(v) \\ \quad - \frac{2.1S(v)I(v)}{5+I(v)}, \quad S(0) = 1.32, \\ \frac{d^{0.7}I(v)}{dv^{0.7}} = 12.6 - 7.97I(v) \\ \quad + \frac{1.89I(v)S(v)}{I(v)+5}, \quad I(0) = 2.29, \\ \frac{d^{0.7}Q(v)}{dv^{0.7}} = 0.59I(v) \\ \quad + \frac{0.21S(v)I(v)}{5+I(v)} - 7.38Q(v), \quad Q(0) = 3.5. \end{array} \right. \quad (4)$$

Case 3: Consider $\eta = 0.5$, $\beta = 2.1$, $\alpha = 5$, $a = 2.6$, $\sigma = 0.59$, $\alpha_1 = 1.78$, $\eta = 1$, $\delta_1 = 0.4$, $\alpha_2 = 1.78$, $\mu = 5.2$, $\delta_2 = 0.4$, $k = 0.1$, $\theta = 0.9$, $m = 14$, $l_1 = 1.32$, $l_2 = 2.29$ and $l_3 = 3.5$ is provided as:

$$\left\{ \begin{array}{l} \frac{d^{0.9}S(v)}{dv^{0.9}} = 4 - 5.2S(v) \\ \quad - \frac{2.1S(v)I(v)}{5+I(v)}, \quad S(0) = 1.32, \\ \frac{d^{0.9}I(v)}{dv^{0.9}} = 12.6 - 7.97I(v) \\ \quad + \frac{1.89I(v)S(v)}{I(v)+5}, \quad I(0) = 2.29, \\ \frac{d^{0.9}Q(v)}{dv^{0.9}} = 0.59I(v) \\ \quad + \frac{0.21S(v)I(v)}{5+I(v)} - 7.38Q(v), \quad Q(0) = 3.5. \end{array} \right. \quad (5)$$

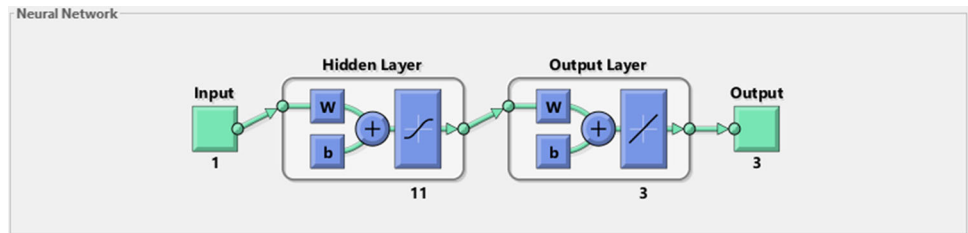
Figure 3 shows the structure of the input/hidden/output layers for the fractional SIQ nonlinear dynamical model using the AI-SCG solver.

The graphical illustrations are provided in Figs. 4, 5, 6 for the fractional SIQ system by using the AI-SCG scheme. To authenticate the optimal measures and STs values, the graphical plots are drawn in Figs. 4, 5. Figure 4 shows the MSE values and STs for the verification, training and best curves to present the solutions of the fractional SIQ mathematical model. The achieved MSE measures for the optimal performances based on the fractional SIQ dynamical system have been illustrated at epoch 1000 for 1st and 3rd case, while for the 2nd case the epoch has been counted as 474. The MSE values for the 1st, 2nd and

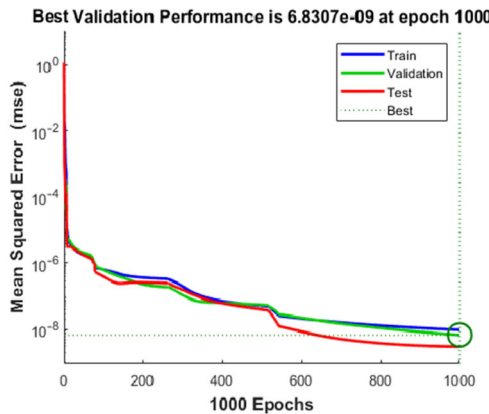
3rd case are 9.80×10^{-09} , 2.26×10^{-08} and 4.25×10^{-09} . The 2nd part of Fig. 4 shows the gradient measures for the fractional SIQ dynamical system by using the AI-SCG procedure, which are performed as 1.00×10^{-08} , 1.00×10^{-08} and 1.00×10^{-08} for case 1, 2 and 3. The convergence of the scheme is observed through these graphical plots for presenting the solutions of the fractional SIQ mathematical system. The fitting curves performances are illustrated in Figs. 5, 6, 7 and 8 for each variation of the fractional SIQ dynamical system. These illustrations indicate the comparative presentations of the achieved and database reference solutions. The illustrations based on the error are drawn in Fig. 5 (a to c) using the training, substantiation and testing measures to present the numerical solutions of the fractional SIQ mathematical system, whereas the EHs plots are drawn in Fig. 5d–f that are calculated as -7.7×10^{-06} , -1.2×10^{-05} and -1.6×10^{-05} for case 1–3. Figure 6a–c presents the regression measures for solving the fractional SIQ dynamical system. Figure 6 indicates the regression performance through the correlation measures. It is observed that the correlation values are found as 1 to solve the mathematical fractional SIQ dynamical system. The correctness is observed through the performances based on the substantiation/training/testing procedures indicating the exactness of the stochastic AI-SCG solver for the mathematical fractional SIQ dynamical system. The convergence operator performances using the MSE measures based on the backpropagation, verification, complexity, training, Epoch and testing are presented in Table 2 for the mathematical fractional SIQ dynamical system. The comprehensive details of the parameters presented as; the authentication measures show the fitness performances, i.e., MSE, means the data samples applied to the authentication, i.e., 7% in total samples, Mu shows the adaptive scale conjugate gradient parameter based on the controlling convergence algorithm coefficient, performance represents the MSE fitness, gradient shows the 1st kind of optimal parameter, and complexity in 2nd shows the amendment of the networks.

Figures 7 and 8 present the comparison of the results along with the AE. These numerical illustrations have been drawn for the mathematical fractional SIQ dynamical system using the stochastic performances of the AI-SCG procedure. The performances based on the reference as well as obtained solutions are drawn in Fig. 7 that have been provided by using the matching of the solutions. The overlapping of the solutions validates the correctness of the AI-SCG scheme to present the mathematical fractional SIQ dynamical system. The values of the AE for the dynamical SIQ system are illustrated in Fig. 8. The AE measures based on the susceptible individuals $S(v)$ performed as 10^{-04} to 10^{-05} , 10^{-04} to 10^{-06} and 10^{-05} to 10^{-06} for 1st to 3rd case. These values for the infected individuals $I(v)$ drawn as 10^{-04} to 10^{-06} , 10^{-04} to 10^{-05} and 10^{-05} to 10^{-06} for respective cases of the system. Likewise, the AE values-based quarantine individuals $Q(v)$ performed as 10^{-05} to 10^{-06} , 10^{-03} to 10^{-04} and 10^{-04} to 10^{-06} . These

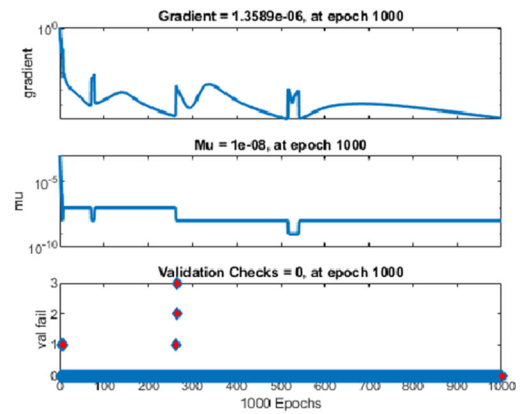
Fig. 3 Neuron structure for the fractional SIQ system



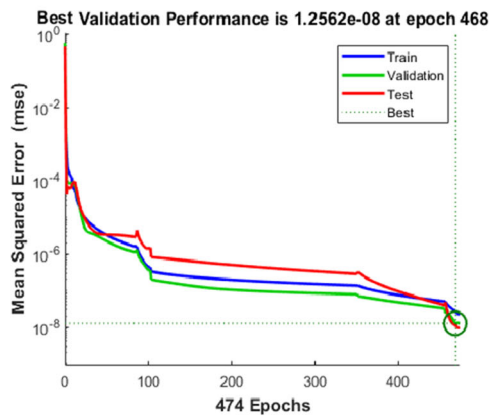
(a) Case 1
MSE
analysis



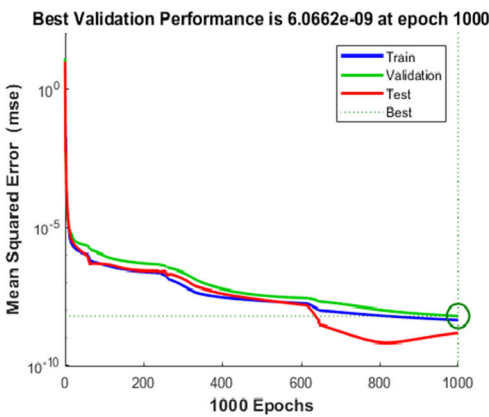
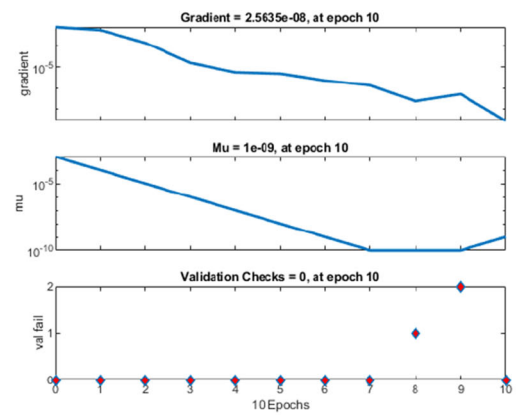
(d) Case I:
STs values



(b) Case 2:
MSE
analysis



(e) Case 2:
STs values



(c) Case 3:
MSE
analysis

(f) Case 3:
STs values

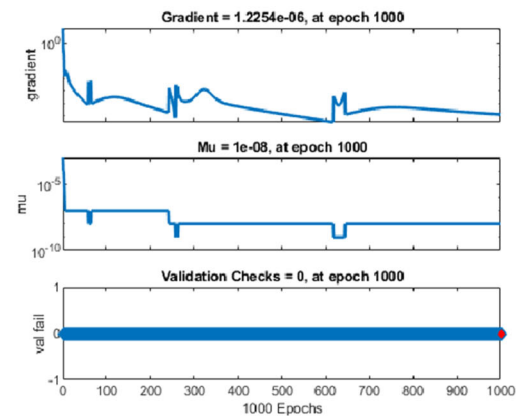
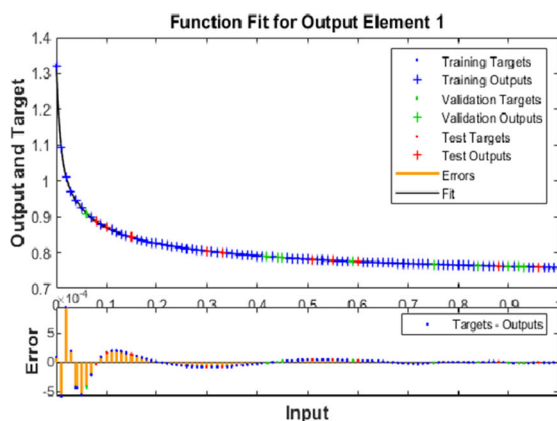
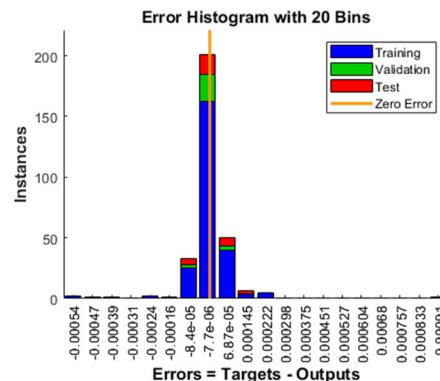


Fig. 4 MSE analysis and STs values for the fractional SIQ nonlinear system

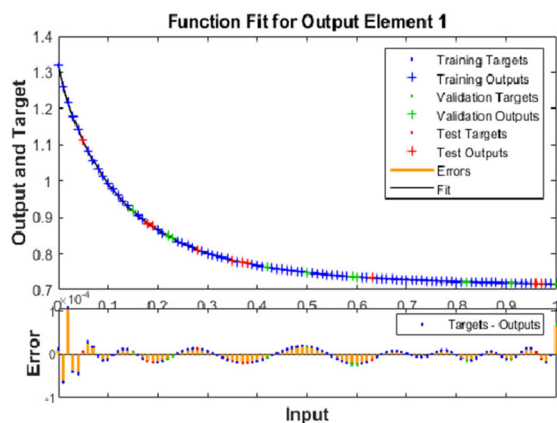
(a) Case 1:
Result
valuations



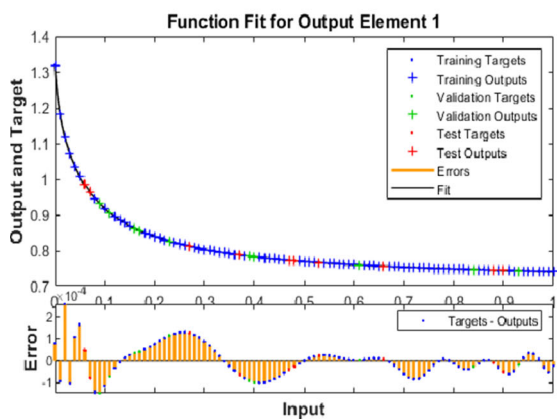
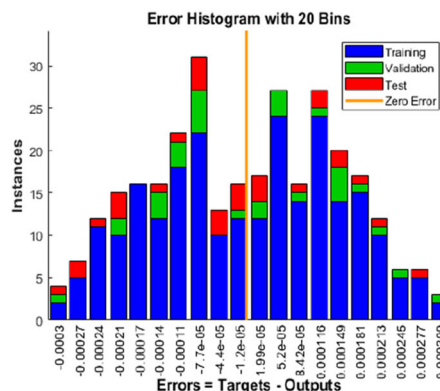
(d) Case I:
EH



(b) Case 2:
Result
valuations



(e) Case 2:
EHs



(c) Case 3:
Result
valuations

(f) Case 3:
EHs

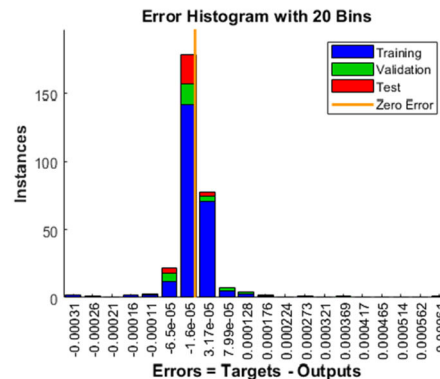
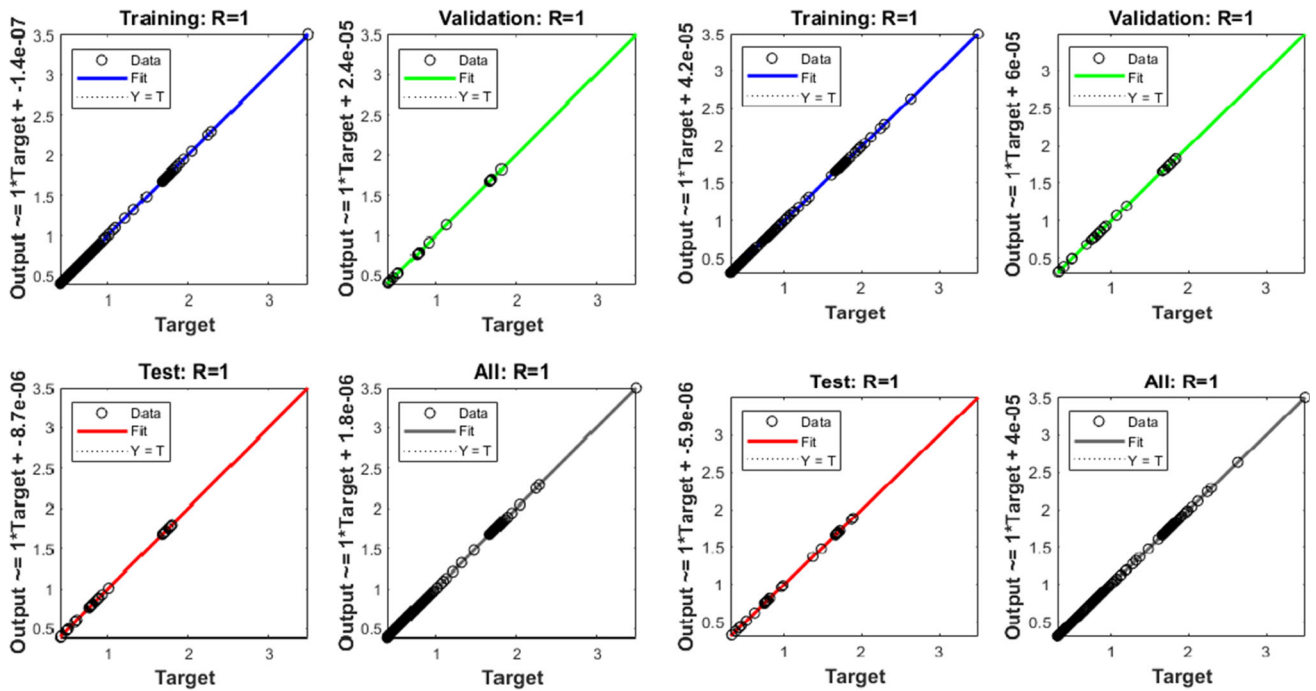
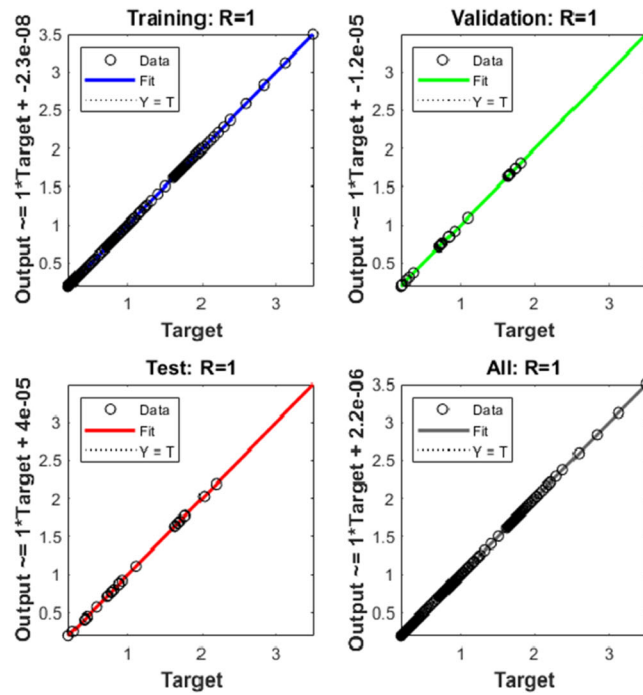


Fig. 5 Result assessments and EHs for the fractional SIQ nonlinear system



(a) Regression: Case 1

(b) Regression: Case 2



(c) Regression: Case 3

Fig. 6 Regression illustrations for the fractional SIQ nonlinear system

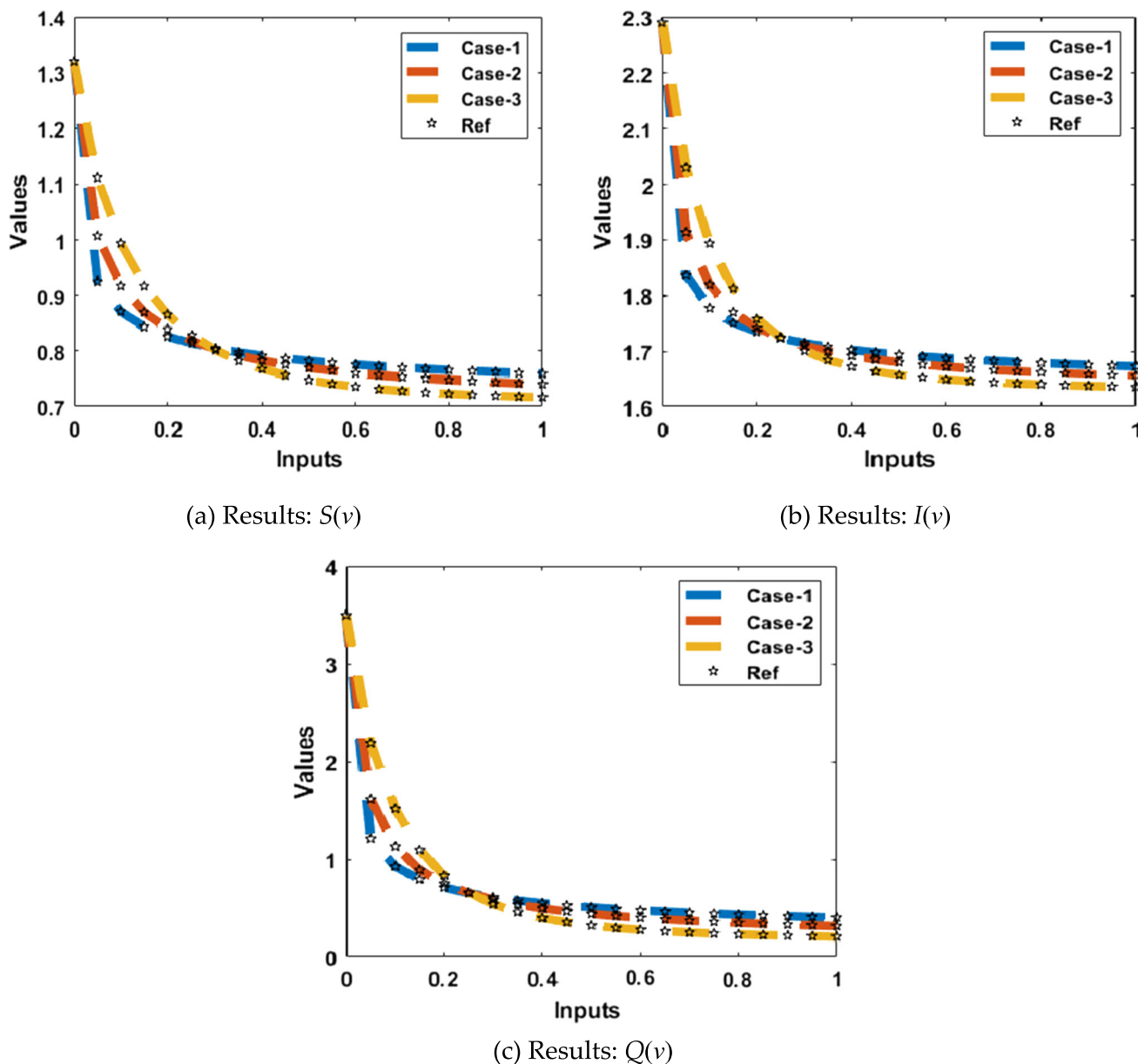


Fig. 7 Result comparisons for the fractional SIQ nonlinear system

illustration-based AE indicate the correctness of the AI-SCG solver to present the numerical solutions of the fractional SIQ dynamical system.

5 Conclusion

The motive of this study is to present the computing numerical procedures based on the fractional mathematical susceptible/infected/quarantine, i.e., a SIQ system of the lockdown impacts using the coronavirus. The fractional-order investigations have been used to provide precise solutions of the SIQ dynamical system. The investigations based on the integer and nonlinear based on the mathematical SIQ dynamical system together with the effects of lockdown have also been presented.

The lockdown impacts are classified into the susceptible/infections/quarantine categories, which is based on the system of differential models. The fractional investigations have been illustrated to investigate the precise as well as accurate solutions of the SIQ system using the artificial intelligence procedure together with the scale conjugate gradient design. Three cases based on the fractional-order derivatives have been presented to solve the nonlinear SIQ differential model. The statics to perform the numerical results of the fractional SIQ dynamical system have been provided as 7% for validation, 82% for training and 11% for testing. To observe the exactness of the AI-SCG procedure, the comparison of the numerical attained performances of the results has been presented with the

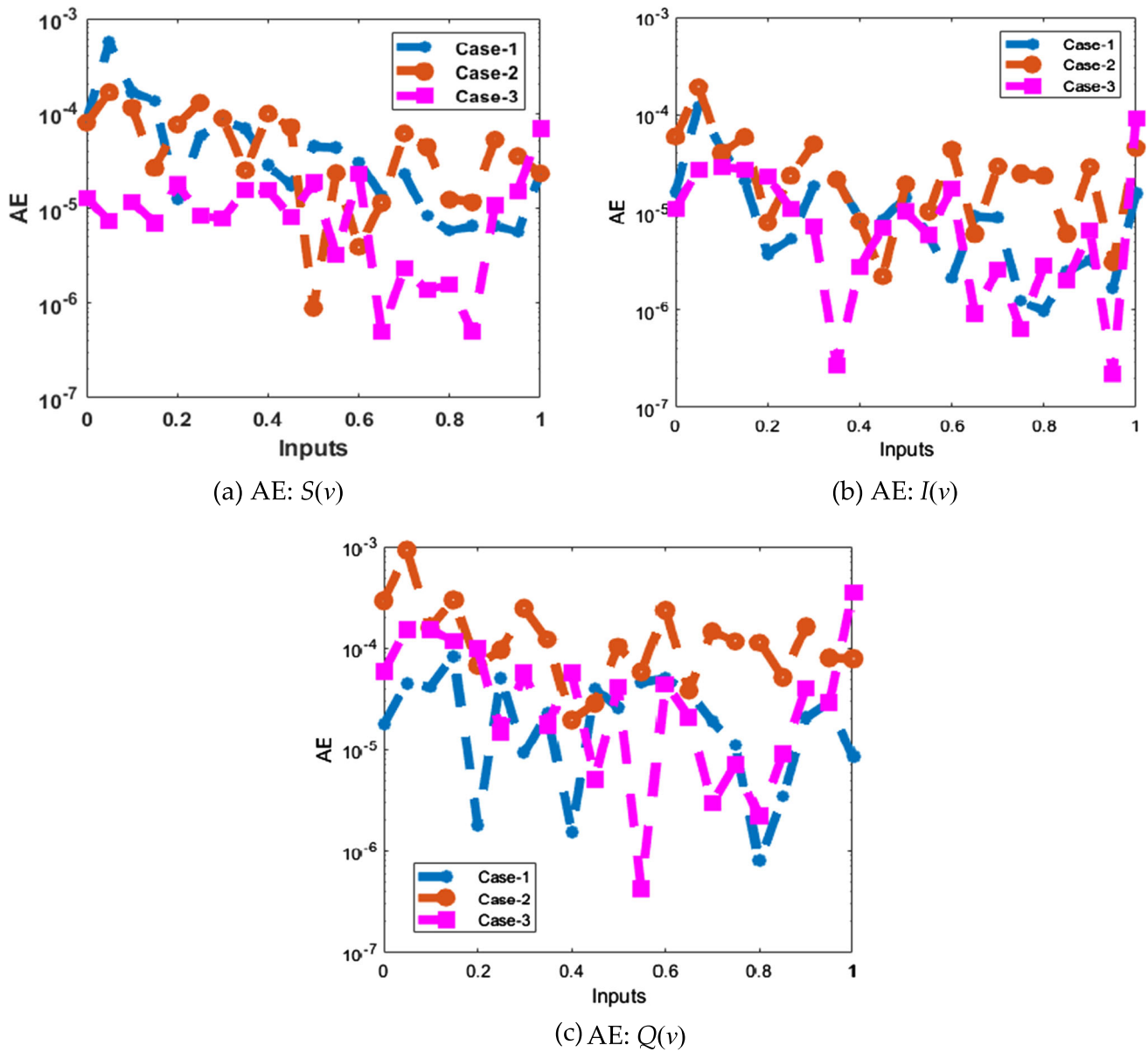


Fig. 8 AE for the fractional SIQ nonlinear system

Table 2 Stochastic performance for the fractional SIQ nonlinear system

Case	MSE			Gradient	Performance	Generation	Mu	Complexity
	Test	Train	Authentication					
1	2.96×10^{-09}	9.79×10^{-09}	6.83×10^{-09}	1.36×10^{-06}	9.80×10^{-09}	1000	1×10^{-08}	05
2	1.17×10^{-08}	2.75×10^{-08}	1.25×10^{-08}	2.02×10^{-06}	2.26×10^{-08}	474	1×10^{-08}	03
3	1.48×10^{-09}	4.25×10^{-09}	6.06×10^{-09}	1.23×10^{-06}	4.25×10^{-09}	1000	1×10^{-08}	05

reference Adam solutions. For the validation, authentication, aptitude, consistency and validity of the AI-SCG solver, the computing numerical solutions have been authenticated based on the state transition measures, error histograms, correlation/regression performances as well as mean square error.

In upcoming studies, the procedure AI-SCG solver can be executed to present the numerical performances of the nonlinear system, biological models as well as computer virus models.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1140/epjs/s11734-022-00738-9>.

Acknowledgements This work is supported by National Research Council of Thailand (NRCT) and Khon Kaen University (Mid-Career Research Grant NRCT5-RSA63003).

Declarations

Conflict of interest There is no conflict of interest. All authors contributed equally.

Data availability statement This manuscript has associated data in a data repository. [Authors' comment: Please see statement 1 in the supplementary materials and notes section for direct access to code and examples for the employed analyses. Access to the data repository will be made available upon request.]

References

1. M. Umar et al., Stochastic numerical technique for solving HIV infection model of CD4+ T cells. *Eur. Phys. J. Plus* **135**(5), 403 (2020)
2. Guerrero-Sánchez, Y., et al. Solving a class of biological HIV infection model of latently infected cells using heuristic approach. *Discrete \quad Continuous Dynamical Systems-S* (2020)
3. M. Umar et al., A stochastic numerical computing heuristic of SIR nonlinear model based on dengue fever. *Results Phys.* **19**, 103585 (2020)
4. Li, Q., et al., 2020. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *New England journal of medicine*.
5. Bhola, J., et al., 2020. Corona epidemic in Indian context: predictive mathematical modelling. *MedRxiv*.
6. M. Umar et al., A novel study of Morlet neural networks to solve the nonlinear HIV infection system of latently infected cells. *Results in Physics* **25**, 104235 (2021)
7. ELSONBATY, A., et al., 2021. Dynamical analysis of a novel discrete fractional sitrs model for COVID-19. *Fractals*, p.2140035.
8. G. Spiteri et al., First cases of coronavirus disease 2019 (COVID-19) in the WHO European Region, 24 January to 21 February 2020. *Eurosurveillance* **25**(9), 2000178 (2020)
9. D. Benvenuto et al., Application of the ARIMA model on the COVID-2019 epidemic dataset. *Data Brief* **29**, 105340 (2020)
10. T. Rhodes et al., Mathematical models as public troubles in COVID-19 infection control: following the numbers. *Health Sociol. Rev.* **29**(2), 177–194 (2020)
11. Mustafa, S.K., et al., 2020. Brief review of the mathematical models for analyzing and forecasting transmission of COVID-19.
12. Nesteruk, I., 2021. Estimates of the COVID-19 pandemic dynamics in Ukraine based on two data sets. *medRxiv*.
13. Sivakumar, A., 2020. Review of mathematical models to predict the rate of spread and control of COVID-19 in India. *Bull World Health Organ*.
14. R.N. Thompson, Epidemiological models are important tools for guiding COVID-19 interventions. *BMC Med.* **18**, 1–4 (2020)
15. G.B. Libotte, F.S. Lobato, G.M. Platt, A.J.S. Neto, Determination of an optimal control strategy for vaccine administration in COVID-19 pandemic treatment. *Comput. Methods Programs Biomed.* **196**, 105664 (2020)
16. A.B. Gumel et al., A primer on using mathematics to understand COVID-19 dynamics: Modeling, analysis and simulations. *Infectious Disease Modelling* **6**, 148–168 (2021)
17. I.Z. Sadiq, F.S. Abubakar, B.I. Dan-Iya, Role of nanoparticles in tackling COVID-19 pandemic: a biomedicine approach. *Journal of Taibah University for Science* **15**(1), 198–207 (2021)
18. F. Ortenzi et al., A transdisciplinary analysis of covid-19 in italy: The most affected country in europe. *Int. J. Environ. Res. Public Health* **17**(24), 9488 (2020)
19. S. Moore et al., Vaccination and non-pharmaceutical interventions for COVID-19: a mathematical modelling study. *Lancet. Infect. Dis* **21**(6), 793–802 (2021)
20. Y.G. Sánchez et al., Design of a nonlinear SITR fractal model based on the dynamics of a novel coronavirus (COVID-19). *Fractals* **28**(08), 2040026 (2020)
21. Sabir, Z., Umar, M., Raja, M.A.Z. and Baleanu, D., 2021. Applications of Gudermannian neural network for solving the SITR fractal system. *Fractals*.
22. Y. Umar, Theoretical studies of the rotational and tautomeric states, electronic and spectroscopic properties of favipiravir and its structural analogues: a potential drug for the treatment of COVID-19. *J. Taibah Univ. Sci.* **14**(1), 1613–1625 (2020)
23. X. Chen et al., Compliance and containment in social distancing: mathematical modeling of COVID-19 across townships. *Int. J. Geogr. Inf. Sci.* **35**(3), 446–465 (2021)
24. A.J.I.D.M. Anirudh, Mathematical modeling and the transmission dynamics in predicting the Covid-19-What next in combating the pandemic. *Infect. Dis. Model.* **5**, 366–374 (2020)
25. Z. Zhang et al., Dynamics of COVID-19 mathematical model with stochastic perturbation. *Adv. Differ. Equ.* **2020**(1), 1–12 (2020)
26. Z. Sabir et al., Numerical investigations of the nonlinear smoke model using the Gudermannian neural networks. *Math. Biosci. Eng.* **19**(1), 351–370 (2022)
27. Z. Sabir et al., An efficient Stochastic numerical computing framework for the nonlinear higher order singular models. *Fractal Fract.* **5**(4), 176 (2021)

28. Z. Sabir et al., Design of Morlet wavelet neural network for solving the higher order singular nonlinear differential equations. *Alex. Eng. J.* **60**(6), 5935–5947 (2021)
29. Z. Sabir, J.L. Guirao, T. Saeed, Solving a novel designed second order nonlinear Lane–Emden delay differential model using the heuristic techniques. *Appl. Soft Comput.* **102**, 107105 (2021)
30. Guirao, J.L., et al., 2020. Design and numerical solutions of a novel third-order nonlinear Emden–Fowler delay differential model. *Mathematical Problems in Engineering*, 2020.
31. Z. Sabir, M.A.Z. Raja, J.L. Guirao, T. Saeed, Meyer wavelet neural networks to solve a novel design of fractional order pantograph Lane–Emden differential model. *Chaos Solit. Fract.* **152**, 111404 (2021)
32. Z. Sabir, M.A.Z. Raja, M. Shoaib, J.G. Aguilar, FMNE-ICS: fractional Meyer neuro-evolution-based intelligent computing solver for doubly singular multi-fractional order Lane–Emden system. *Comput. Appl. Math.* **39**(4), 1–18 (2020)
33. T. Botmart, Z. Sabir, M.A.Z. Raja, W. Weera, R. Sadat, M.R. Ali, A numerical study of the fractional order dynamical nonlinear susceptible infected and quarantine differential model using the stochastic numerical approach. *Fractal Fract.* **6**(3), 139 (2022)
34. S.D. Bolboacă, L. Jäntschi, Sensitivity, specificity, and accuracy of predictive models on phenols toxicity. *J. Comput. Sci.* **5**(3), 345–350 (2014)
35. L. Jäntschi, S.D. Bolboacă, R.E. Sestraş, Meta-heuristics on quantitative structure–activity relationships: study on polychlorinated biphenyls. *J. Mol. Model.* **16**(2), 377–386 (2010)
36. K. Mukdasai, Z. Sabir, M.A.Z. Raja, R. Sadat, M.R. Ali, P. Singkibud, A numerical simulation of the fractional order Leptospirosis model using the supervise neural network. *Alex. Eng. J.* **61**(12), 12431–12441 (2022)
37. Chen, Q., Sabir, Z., Raja, M.A.Z., Gao, W. and Baskonus, H.M., 2022. A fractional study based on the economic and environmental mathematical model. *Alexandria Engineering Journal*.
38. A.H. Bukhari, M.A.Z. Raja, N. Rafiq, M. Shoaib, A.K. Kiani, C.M. Shu, Design of intelligent computing networks for nonlinear chaotic fractional Rossler system. *Chaos Solit. Fract.* **157**, 111985 (2022)

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.