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RESEARCH ARTICLE

Numerical Assessments Employing Neural Networks for a Novel Drafted Anti-Virus Subcategory in a Nonlinear Fractional-Order SIR Differential System

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ABSTRACT Whereas computer viruses (CVs) are a terrible threat to individual and corporate computer structures. A considerable attempt has been made to research ways to prevent their negative consequences, to develop anti-virus software that behave as vaccines in desktop computers or strategic network nodes. A further method for combating viral transmission is to develop preventative strategies associated with a given performance of a network that may be described using population models compared to the few employed with epidemiological analyses. An updated variation of such *SIR* (Susceptible-Infected-Removed) framework is offered here, along with an explanation of whether these parameters correspond to network properties. The novel formed *SAIR* model is then numerically treated, employing the qualities of stochastic procedure-based numerical computation approaches that use neural networks (NNs). In this research study, we suggest novel fractional-order SAIR (FO-SAIR) differential model that has not previously been published. This study's aim appeared to be to demonstrate the effects and applicability of such FO-SAIR differential scheme. An FO-SAIR problem is examined using stochastic solvers relyed upon Levenberg-Marquardt backpropagation approach (L-MB) and NNs, specifically L-MBNNs. For solve the FO-SAIR system, three examples with different values under the same fractional order are presented. The statistical methods used to generate numerical answers for the FO-SAIR system are categorised thus obeys: 75% for training, 13% for testing, and 12% for permission. By using Adams-Bashforth-Moulton, the numerical results were contrasted with the reference solutions to determine the accuracy of such L-MBNNs. To confirm overall capability, competence, validity, consistency, and exactness, the numerical performances of these L-MBNNs using error histograms (EHs), state transitions (STs), regression, correlation, and mean square error (MSE) are also shown.

INDEX TERMS Fractional-order, neural networks, Levenberg-Marquardt backpropagation scheme, anti-virus software, Adams-Bashforth-Moulton.

I. INTRODUCTION

Any piece of damaging software code intended for transmission from transmitter to receiver is referred to as a computer virus. Such malware and self-copying attacks frequently aim

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to damage the system or steal data. Think of any biological virus, the sickening variety. It frequently necessitates the use of a potent antidote to be removed and is consistently awful, impairing capacity to function properly. That is very similar to the computer virus. CVs destroy your apps and data, change how your computer functions, or entirely disable it. They are designed to multiply eternally. Some CVs are often made to harm the computer by erasing data, altering software, or even reformatting the entire hard drive. Some replicate themselves or flood the connection with traffic, making it impossible to use the internet further. However, fewer dangerous computer infections can substantial impact the system 's efficiency by consuming memory space or triggering numerous computer breakdowns.

Globalization and the advancement in communication technologies significantly increased the presence of computers in human daily lives. Cell phones, portable items, laptops, MP3 players, and various electronic gadgets have strengthened people's reliance on computers. The enormous amount of current CVs and an associated more significant amount of destructiveness seem to become a key danger element for organizations and people throughout this environment. CVs include little algorithms designed to harm computer networks by destroying data, extracting material, or altering normal functioning. Traditional epidemiological configurations regarding disease spread may be used to study its dynamics over a system [1], [2]. Such virus programs now have more complicated codes and may develop mutations of themselves, making identification and eradication by antiviral tools better challenging [2]. Furthermore, they can obtain private information about network consumers, including passwords and bank identities, inflicting significant harm to people and companies [3]. As a result, research into precisely comprehending computer virus propagation patterns is critical to enhancing the security and dependability of computer platforms [1], [4]. Based on biological principles, there seem to be two approaches to addressing challenges: microscopic as well as macroscopic [5], [6], [7].

Regarding a microscopic framework, a formal document by Kephart et al. [5] was publicly released in the delayed 1980s, activating investment in the advancement of anti-virus software, held to account for virus identification as well as elimination, relying on the preceding acknowledgement of the contagion code depending on prototypes established in [2], [6], and [7]. These algorithms possess tremendous upgrade potential, yet they serve only as essential disease vaccines [2], [4]. Furthermore, they cannot to foresee network behavior whenever an outbreak is formed in a system and, as a result, cannot provide a precautionary attitude towards viral behaviors related to network occurrences [2], [8].

Additionally, throughout the 1980s [6], another macroscopic method, including models for such transmission for CVs depending on underlying epidemiological equivalents was presented, demonstrating that the long-term characteristics of viral dissemination may be obtained by studying the entire network structures graph. This method has been effectively used in electronic mail dissemination systems [9], and adjustments to SIR designs produced infection prevention guidelines while employing the notion of underlying epidemiological thresholds [1], [10], [11], [12].

Given that specific platform, workstations may be loaded using anti-virus programming, and SIR models would modified to incorporate frame reflecting an antidotal population, resulting in SAIR (where A denotes antidotal term) structure explored in [1] and [13]. Finally, considering a network's operational norms, a variation of such SAIR framework is presented and investigated, yielding some insights regarding preventative attitudes.

In this research, we analyze the FO-SAIR system and then develop the FO necessary criteria for the occurrence of stable results. Additionally, using the SAIR framework, we create stochastic structure to solve FO differential system. An integer, the nonlinear differential system was also incorporated in the complete analysis the newest recommended antidotal population used to modify the SIR system. Stochastic solvers relying upon Levenberg-Marquardt backpropagation technique (L-MB) as well as neural networks (NNs), particularly L-MBNNs employed for assess the FO-SAIR system. The intelligent computing via neural networks aided with efficient learning system has been exploited effectively in different applications [14], [15], [16], [17], [18]. Through thorough simulations, we offered proposed L-MBNNs in this study for the investigation of three scenarios with various FO values in the FO-SAIR system.

II. MATHEMATICAL DESIGN OF THE FO-SAIR SYSTEM

The framework described below is an extension of the classic compartmental SIR system [19], incorporating a community of antidotes division (A), indicating an entire network equipped with completely effective anti-virus software [1], [13]. Figure 1 depicts the SAIR model's process diagram. Process diagrams, often known as ''flow diagrams,'' represent an overall chain of actions in a system. Process modeling specifies activities and outlines how they should be carried out. Flow diagrams depict process participants, activity sequences, information transferred throughout a process, and activity triggers. Processes may also describe the many inspections, options, and arranging present within a series of actions. Depending on the aim of the model, processes can be represented in varying levels of context.

Connectivity across divisions reflect network operating characteristics, and their regulation may be employed as a method to preserve overall system dependability, even in the face of diseases, find Figure 1 [20]. About the whole community T has been separated into four communities: S of those computers which are not infected and at risk of infection; A of those computers which are not infected but equipped using anti-virus software; I for infected computers; as well as R for removed machines, whether infected or not. The model's influx, as well as mortality factors, are as follows:

The rate of influx, which represents the addition of new computers toward the network is represented as M.

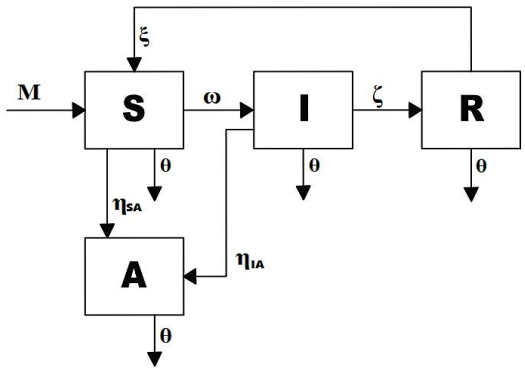


FIGURE 1. The SAIR mathematical model's process description.

The fraction coefficient for the death rate that is not caused by the virus is given as θ.

The susceptible sector S becomes infected at such a rate proportional to the likelihood of susceptible computers establishing successful connections with infected computers. As a result, such a rate is equivalent to a product SI, with ω being the proportion element.

The ratio of susceptible to antidotal changes the operational parameter and in accordance with production SA η_{SA} determined by the network administrator's anti-virus deployment plan. Anti-virus applications can be changed into antidotal ones at a rate proportional to AI to fix infected machines, with percentage variable supplied via η_{IA}, they can get ineffective as well as be eliminated at rate set via ζ. Removable computers could via a percentage factor of ξ, restored as well as turned into susceptible. As might be seen, our model describes the characteristics of a recognized virus's infection; therefore. As a result, the conversion from antidotal infected seems not considered. As a result of adopting such a model, a vaccination strategy might be created, allowing for the most cost-effective usage of anti-virus solutions. Given these data, the model may be stated as follows:

$$\begin{cases} S'(\mathfrak{T}) = M - \eta_{SA}SA - \omega SI - \theta S + \xi R, \\ A'(\mathfrak{T}) = \eta_{AI}AI - \zeta I - \theta I, \\ I'(\mathfrak{T}) = \zeta I - \xi R - \theta R, \\ R'(\mathfrak{T}) = \eta_{IA}IA + \eta_{SA}SA - \theta A. \end{cases} \tag{1}$$

Overall influx rate is assumed to be $M = 0$ in this case, indicating that no newer computers are added to the network while the transmission of the investigated virus, since such activity is quicker than network expansion. The decision of $\theta = 0$ is further justified by the fact that the machine's obsolescence period is greater than the time of virus activation. As a result, the equation system (1) is reduced to:

$$\begin{cases} S'(\mathfrak{T}) = -\eta_{SA}SA - \omega SI + \xi R, \\ A'(\mathfrak{T}) = \eta_{AI}AI - \zeta I, \\ I'(\mathfrak{T}) = \zeta I - \xi R, \\ R'(\mathfrak{T}) = \eta_{IA}IA + \eta_{SA}SA. \end{cases} \tag{2}$$

The numerical studies of the FO derivatives of SIR nonlinear model relying upon an antidotal population division, i.e. FO-SAIR system (3), which is derived from (2) have been offered in the current work by employing artificial intelligence (AI) using that implementation of L-MBNNs. The FO derivatives of the SAIR nonlinear model are designed as follows:

$$\begin{cases} \mathcal{D}^{\beta}S(\mathfrak{T}) = -\eta_{SA}SA - \omega SI + \xi R, \\ \mathcal{D}^{\beta}A(\mathfrak{T}) = \eta_{AI}AI - \zeta I, \\ \mathcal{D}^{\beta}I(\mathfrak{T}) = \zeta I - \xi R, \\ \mathcal{D}^{\beta}R(\mathfrak{T}) = \eta_{IA}IA + \eta_{SA}SA. \end{cases} \tag{3}$$

In the system mentioned above, where β represents the FO derivative.

It is vital to note that all aggregate population of such system T=S+A+I+R stays unchanged for such model described by the system (3). As a result, the state-space dimension increases to three, meaning each among these equations may expressed as either a linear combination for any of three remaining.

III. EFFECTIVE PROFILES, AS WELL AS AN ASSESSMENT OF STOCHASTIC SOLVERS

Numerical stochastic operators through L-MBNNs are proposed to resolve either FO-SAIR system. Numerous nonlinear, complicated, stiff, and unique systems are being solved utilising stochastic computer solvers, with the performance of local and global operators being a key component [21], [22], [23]. [24] the third type of nonlinear singular model, singular models of fractional order [25], [26], [27], [28].

Meyer fractional wavelet neural network (MFWNN) is the foundation of ground-breaking stochastic computational approach of fractional nonlinear-singular Lane-Emden (FNSLE) model. The modelling power for MFWNN is used as convert differential NS-FLE model in difference equations as well as approximation theory on the sense of mean squared error is applied in order to construct merit function of FNSLE differential equations. In this paper, we concentrated attention on the functional order model [29]. This publication describes the design of a novel model using nonlinear third-order Emden-Fowler delay differential (EFDD) equations, and two types that use concept of delay differential via conventional second-order EF equation format. The delayed differential model [30] and the periodic differential model [31] show a few examples for well-implemented solvers of this kind. The purpose of this work is to develop numerical representations of the FO derivatives of a differential system based on SAIR paradox using stochastic methods for L-MBNNs. It is discovered that there are numerous ways to define system conditions using time-fractional order derivatives. While the derivative order structure communicates memory, The derivative of fractional order is expressed in the memory retention. More of these fractional derivatives, [32], [33], [34] provide genuine implementations.

According to preliminary research, L-MBNNs of differential FO system using SAIR system include the following crucially novel features:

- By depending on specific SAIR effects new layout by its FO derivatives that underlies SAIR system is addressed.
- Basic FO derivatives of a SAIR system that depended on SAIR effects were never solved using stochastic methods.
- The FO derivatives of the SAIR system, which are based on the SAIR studies effects, are used to demonstrate the effectiveness of computational research embracing stochastic principles.
- Utilizing L-MBNN structure, AI is used to address nonlinear FO derivatives of SAIR systems that depend on SAIR impacts.
- To verify the dependability of the proposed approach, three suitable FO variations based on the FO-SAIR system have been numerically solved.
- By contrasting the generated as well as reference (Adams-Bashforth-Moulton) solutions, stochastic computing solver-based L-MBNNs' superiority is shown.
- The absolute error (AE) performances attained when resolving FO-SAIR model serve as a gauge for the validity of the scheme.
- Performances in the areas of regression, STs, MSE, EHs, and correlation demonstrate the reliability and consistency of the constructed L-MBNNs in solving the FO-SAIR system.

IV. SUGGESTED METHODOLOGY: L-MBNNs

This section describes the suggested L-MBNNs structure for resolving the FO-SAIR system-linked fractional order immune-chemotherapeutic treatment model. There are two parts to the strategy. The basic L-MBNNs operator performances are first shown. While this is going on, the FO-SAIR system is being solved using the L-MBNNs execution method.

Figure 2 shows a multi-layer optimization method using single-layer neurons and numerical stochastic L-MBNNs. The '*nftool*' command in Matlab is used to supply the L-MBNNs processes, with data selected as 75% to SAIR, 13% for testing, and 12% for authorization

V. RESULTS OBTAINED EMPLOYING THE PLANNED METHOD

This phase demonstrates numerical performances with three potential FO changes to address the nonlinear FO-SAIR system using recommended L-MBNNs. The following is the differential explanation of every variable in the related cases:

Case 1: The following FO SAIR-related system should be used the specified values. $\beta = 0.5,\ \eta_{SA} = 0.1,\ \eta_{AI} = 0.3,$ $\eta_{IA} = 0.2,\ \zeta = 0.25,\ \omega = 0.2,\ \xi = 0.15$:

$$\begin{cases} \mathcal{D}^{0.5}S(\mathfrak{T}) = -0.1\ SA - 0.2\ SI + 0.15\ R, S_0 = 0.2, \\ \mathcal{D}^{0.5}A(\mathfrak{T}) = 0.3\ AI - 0.25\ I, A_0 = 0.4, \\ \mathcal{D}^{0.5}I(\mathfrak{T}) = 0.25\ I - 0.15\ R, I_0 = 0.6, \\ \mathcal{D}^{0.5}R(\mathfrak{T}) = 0.2\ IA + 0.1\ SA, R_0 = 0.8. \end{cases} \tag{4}$$

Case 2: The following FO SAIR-related model should be used with the specified values

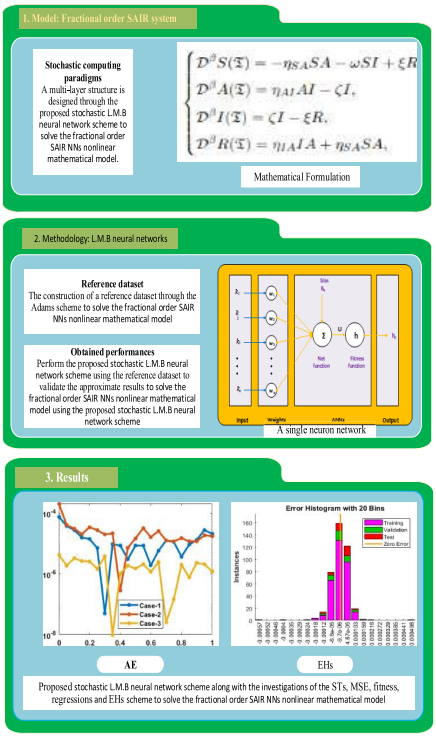


FIGURE 2. L-MBNNs workflow mechanism to solve the FO-SAIR-associated model.

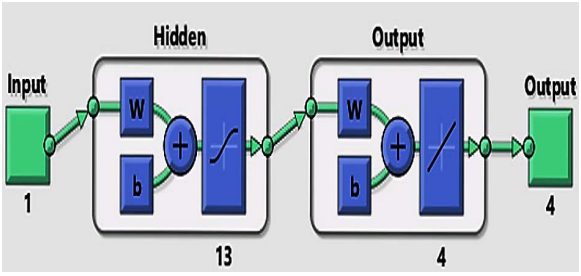


FIGURE 3. L-MBNNs developed for addressing FO SAIR-related model.

$\beta = 0.7,\ \eta_{SA} = 0.1,\ \eta_{AI} = 0.3,$ $\eta_{IA} = 0.2,\ \zeta = 0.25,\ \omega = 0.2,\ \xi = 0.15$:

$$\begin{cases} \mathcal{D}^{0.7}S(\mathfrak{T}) = -0.1\ SA - 0.2\ SI + 0.15\ R, S_0 = 0.2, \\ \mathcal{D}^{0.7}A(\mathfrak{T}) = 0.3\ AI - 0.25\ I, A_0 = 0.4, \\ \mathcal{D}^{0.7}I(\mathfrak{T}) = 0.25\ I - 0.15\ R, I_0 = 0.6, \\ \mathcal{D}^{0.7}R(\mathfrak{T}) = 0.2\ IA + 0.1\ SA, R_0 = 0.8. \end{cases} \tag{5}$$

Case 3: The following FO SAIR-related model should be used with the specified values $\beta = 0.9,\ \eta_{SA} = 0.1,\ \eta_{AI} = 0.3,$ $\eta_{IA} = 0.2,\ \zeta = 0.25,\ \omega = 0.2,\ \xi = 0.15$:

$$\begin{cases} \mathcal{D}^{0.9}S(\mathfrak{T}) = -0.1\ SA - 0.2\ SI + 0.15\ R, S_0 = 0.2, \\ \mathcal{D}^{0.9}A(\mathfrak{T}) = 0.3\ AI - 0.25\ I, A_0 = 0.4, \\ \mathcal{D}^{0.9}I(\mathfrak{T}) = 0.25\ I - 0.15\ R, I_0 = 0.6, \\ \mathcal{D}^{0.9}R(\mathfrak{T}) = 0.2\ IA + 0.1\ SA, R_0 = 0.8. \end{cases} \tag{6}$$

Implementing stochastic L-MBNNs processes with 13 neurons and presenting simulations of the FO SAIR-related

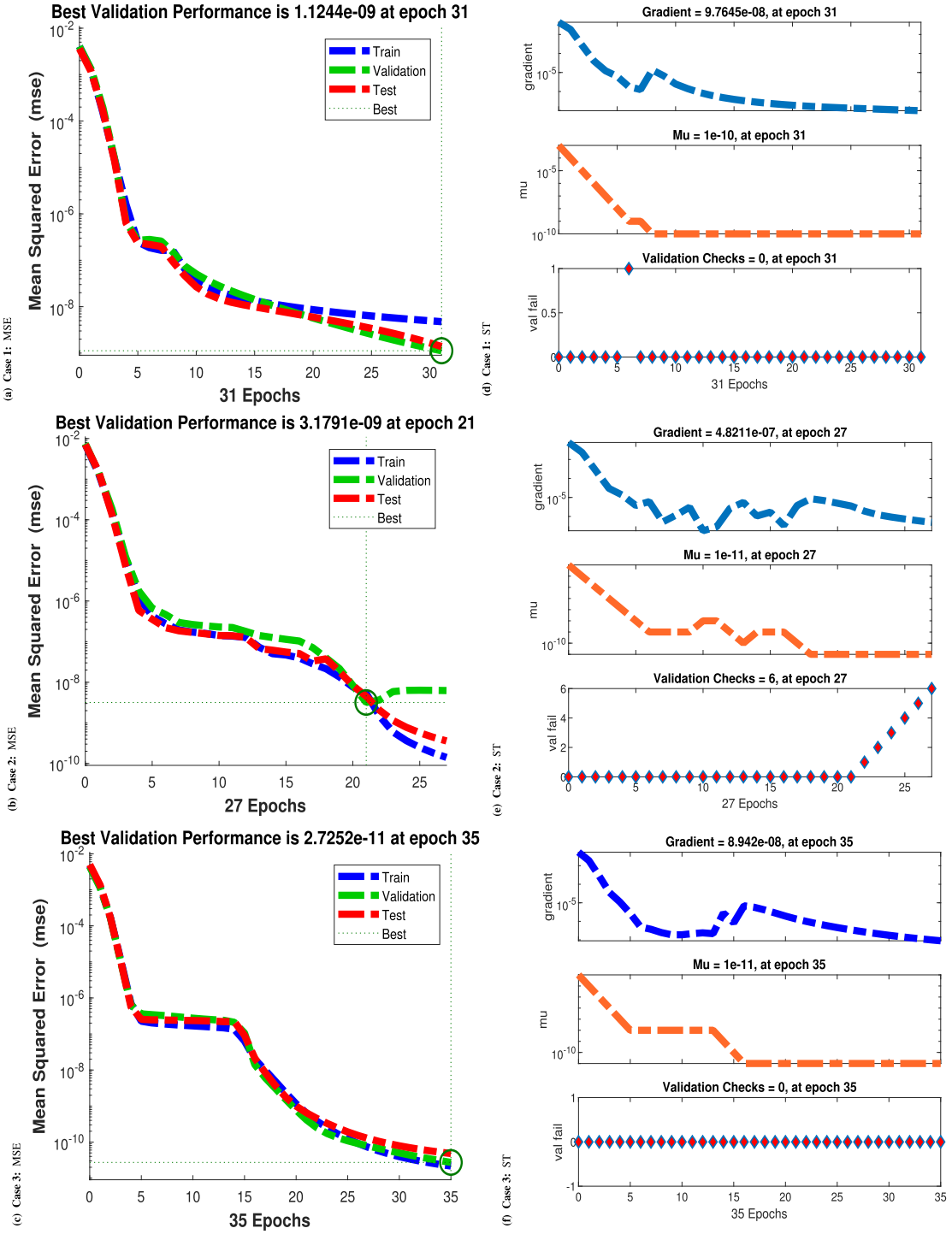


FIGURE 4. TSs along with MSE performances for solving the FO-SAIR system.

model numerically with data selection made up of 75% for training, 13% for testing, and 12% for authorization The hidden, output, and input structures of a neuron are shown in Figure 3.

The visual depictions utilized to examine the FO SAIR-associated scheme using L-MBNNs procedures displayed in Figures 4-6. The finest ST performances are examined using the graphical representations in Figures 4 and 5. MSE and STs values of training, best curves, and authentication are generated in Figure 4 to solve the FO-SAIR system. Based on the most accurate results of such FO-SAIR system at epochs 31, 21, and 35, the resulting values are, respectively, 1.1244×10^{-09}, 3.1791×10^{-09}, and 2.7252×10^{-11}. As part of the L-MBNN-based solution to FO SAIR-related

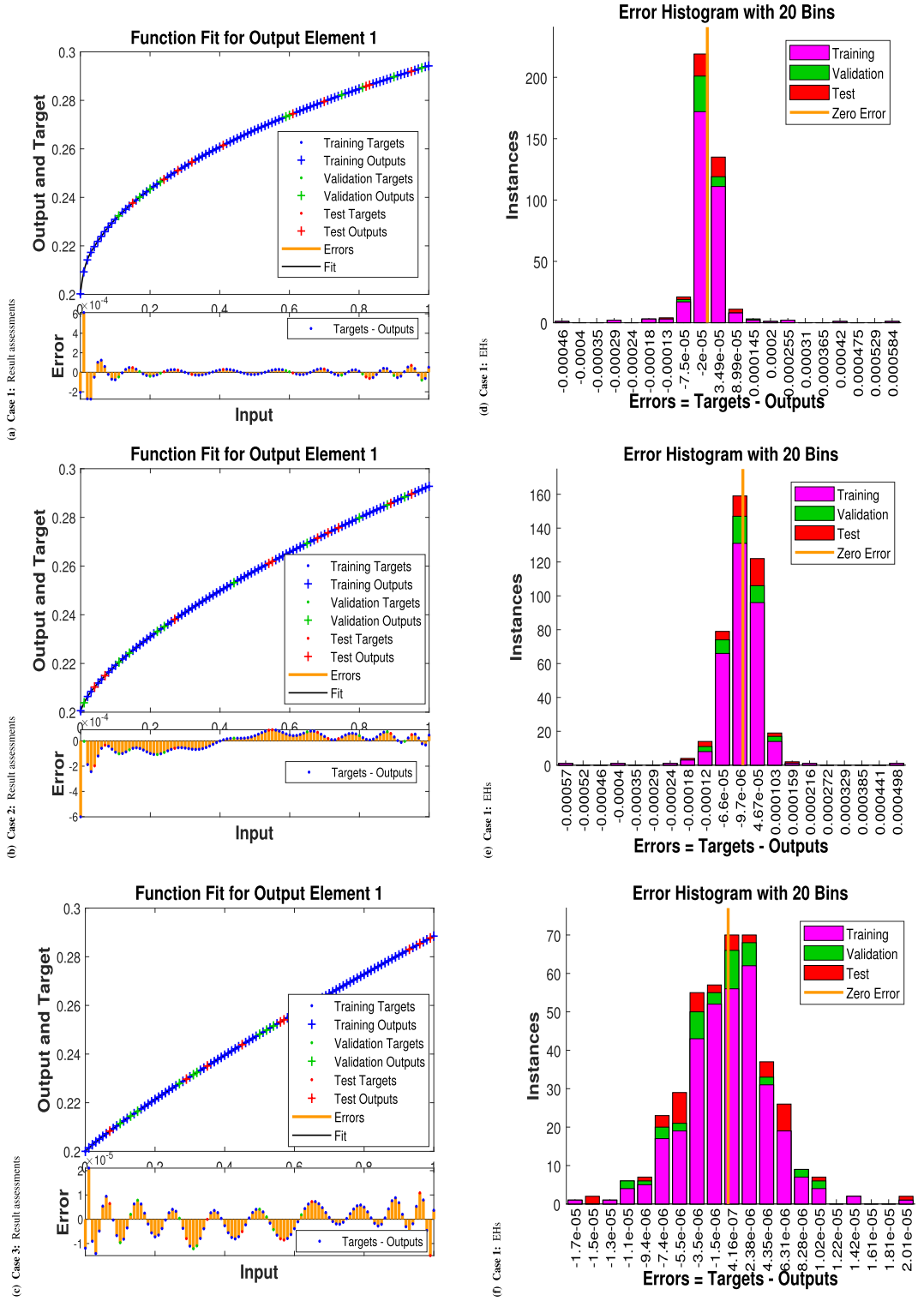
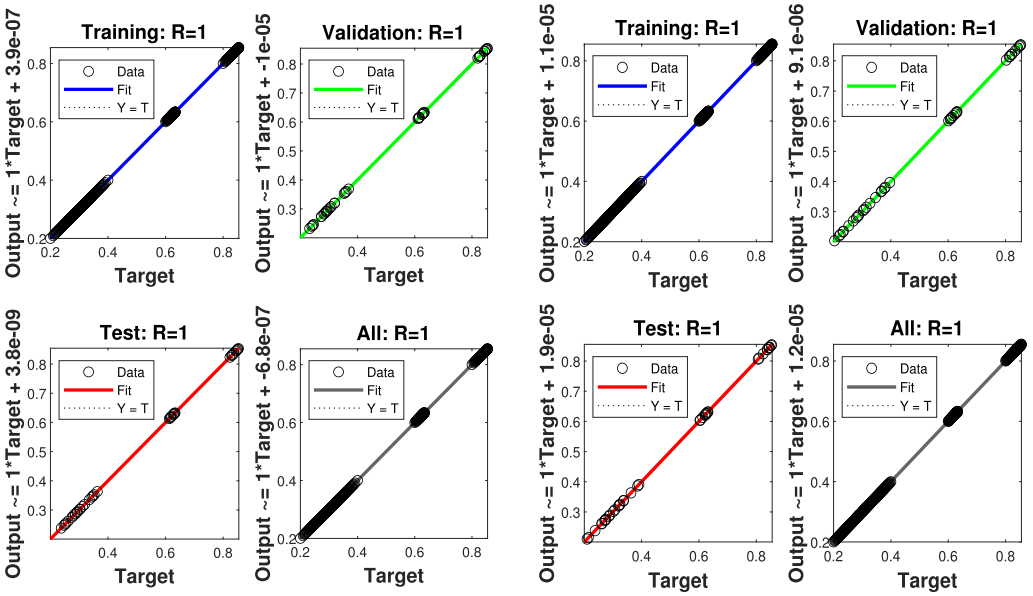


FIGURE 5. Results valuations and EHs for FO-SAIR system.

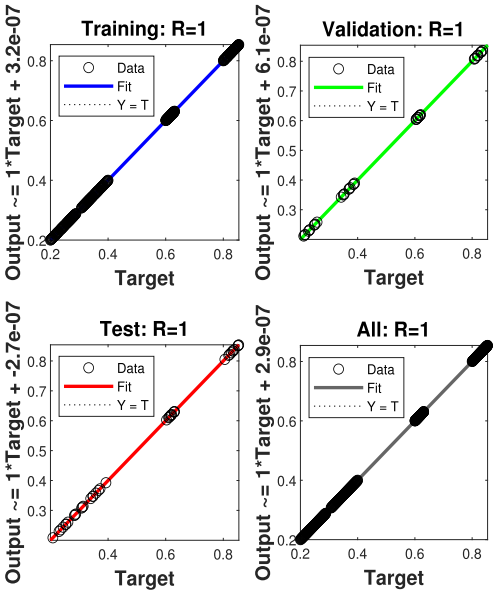
differential model shown in Figure 4, overall gradient data are also plotted. Their gradient values were calculated to be 9.7645×10^{-8}, 4.8211×10^{-7}, as well as 8.942×10^{-8} for scenarios 1, 2, and 3, correspondingly.

These graphical representations show how recommended L-MBNNs converge to solve the FO-SAIR differential model using L-MBNNs. The values of the fitting curves utilized to address each instance for the suggested FO-SAIR differential system are shown in Figures 6-8.

These visualisations contrast the results of the obtained and reference results. The validation, testing, and training of the FO SAIR-associated differential model are represented



(a.) Regression plots: **Case 1**. (b.) Regression plots: **Case 2**.]



(c.) Regression plots: **Case 3**.

FIGURE 6. Regression plots to solve a FO-SAIR system.

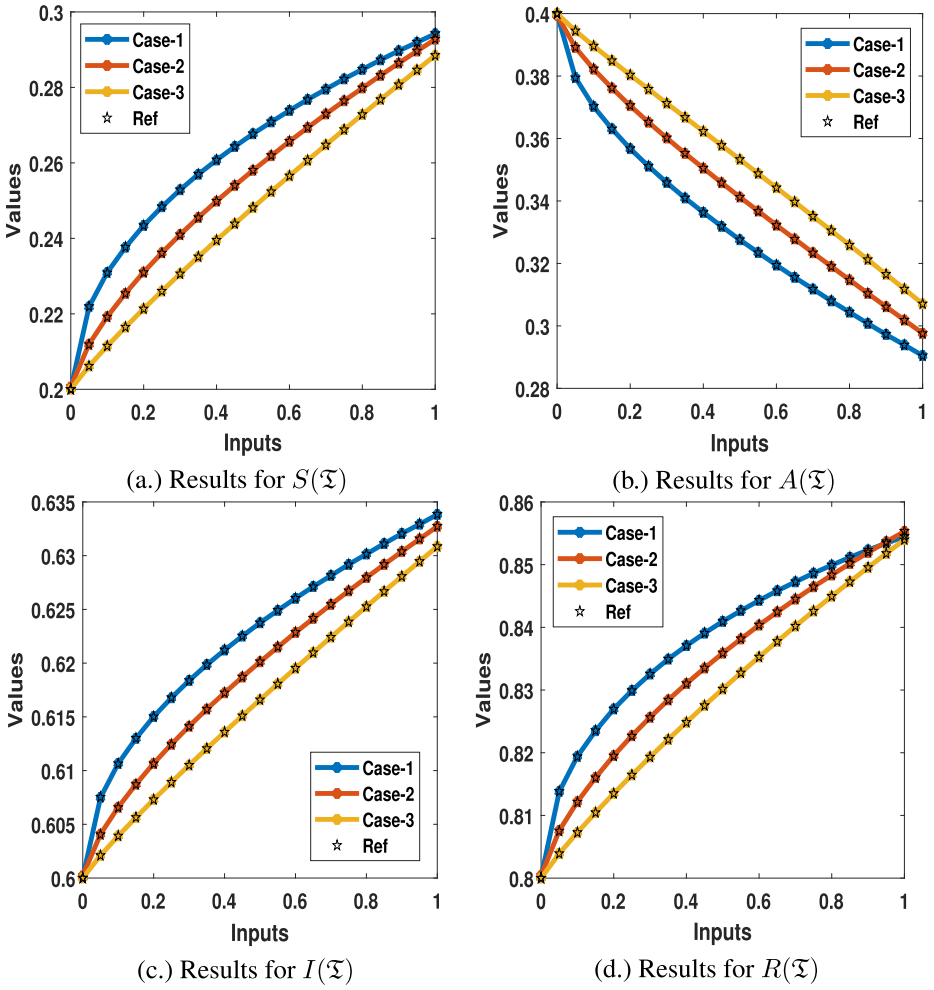
by error graphs. Several EHs are shown in Figures 5(d to f), and corresponding regression measures are provided. These are based on the FO SAIR-associated differential model (a to c). The EHs are comp[uted as -2×10^{05}, -9.7×10^{06}, and 4.16×10^{07} for situations 1, 2, and 3, accordingly.

The connection has been shown in Figure 6 to support the effectiveness of the regression. For the FO SAIR-linked differential model, such correlation maps are calculated as 1. The formulas for training, testing, and authentication show that the stochastic L-MBNNs method for solving the FO-SAIR differential model is valid. The convergence of the MSE, complexity, training, authentication, iterations, testing, and backpropagation-based differential model related to FO SAIR is shown in Table 1.

TABLE 1. The L-MBNNs procedure is adopted to solve the FO differential model of SAIR.

Case	MSE			Gradient	Performance	Epoch	Mu	Time
	Validation	Testing	Training					
1	1.124×10^{-09}	1.386×10^{-09}	4.752×10^{-09}	9.76×10^{-08}	4.75×10^{-09}	31	1×10^{-10}	02
2	3.179×10^{-09}	4.516×10^{-09}	5.317×10^{-09}	4.82×10^{-07}	1.41×10^{-10}	27	1×10^{-11}	02
3	2.725×10^{-11}	4.8097×10^{-11}	2.163×10^{-11}	8.94×10^{-08}	2.16×10^{-11}	35	1×10^{-11}	02

The plotting of result comparisons and AE values is shown in Figures 7-8. Numerical formulas are provided to handle the stochastic L-MBNN-based FO-SAIR system. Figure 7 displays overlapping results for reference as well derived numerical performances. The overlapping outcome confirms the L-MBNNs' accuracy in resolving the differential model linked to the FO SAIR.



(a.) Results for $S(\mathfrak{T})$ (b.) Results for $A(\mathfrak{T})$

(c.) Results for $I(\mathfrak{T})$ (d.) Results for $R(\mathfrak{T})$

FIGURE 7. Result founded upon a FO-SAIR based system.

The AE parameters used to solve the FO-SAIR model are shown in Figure 8. In the kinetics of $S((T))$, the AE values for examples 1 to 3 are located between 10^{-04} and 10^{-06} and 10^{-05} and 10^{-07}. For examples 1 through 3, the AE for $I((T))$ has been determined as $10^{-04}-10^{-07}$, $10^{-04}-10^{-06}$, as well as $10^{-05}-10^{-08}$, respectively. In the same way, for examples 1 through 3, the AE for $R((T))$ was calculated as $10^{-04}-10^{-06}$, $10^{-04}-10^{-07}$, and $10^{-05}-10^{-08}$.

The AE results demonstrate how effectively suggested L-MBNNs serviced the FO-SAIR scheme.

VI. CONCLUSION

The study documented here is connected to introducing of a compartmental model for viral dissemination through computer networks created based on disease transmission models. The FO-SAIR model appears to satisfactorily correspond to the real-world data and be resilient under parameter adjustments. For this created SAIR nonlinear model, a stochastic Levenberg-Marquardt backpropagation neural network is being used. This article outlines the numerical representations of the differential system relyed on FO-SAIR. In order to provide more precise system performances, this study tries to provide a FO assessment using a different model that is centered on the dynamics of an FO-SAIR-based system. About all community T has been separated into four communities: S of those computers which are not infected at risk of infection; A of those computers which are not infected but equipped using anti-virus software; I for infected computers; as well as R for removed machines, whether infected or not. Overall numerical performance of the FO-SAIR-based SAIR differential system or its solution using stochastic Levenberg-Marquardt backpropagation neural networks has never been disclosed. Three instances with different FO ratios have been presented in order to resolve FO-SAIR differential model. The following categories describe the data utilized to provide the FO-SAIR-based model's numerical solutions: 75% for instruction, 13% for testing, and 14% for authorization. 13 neurons were used to demonstrate the numerical performances of the FO-SAIR relyed model. The numerical results of the Adams-Bashforth-Moulton differential system and the FO-SAIR-based system were compared. In order to reduce the MSE, L-MBNNs were used to create the provided numerical findings. The reliability and competence of L-MBNNs are illustrated, along with their numerical

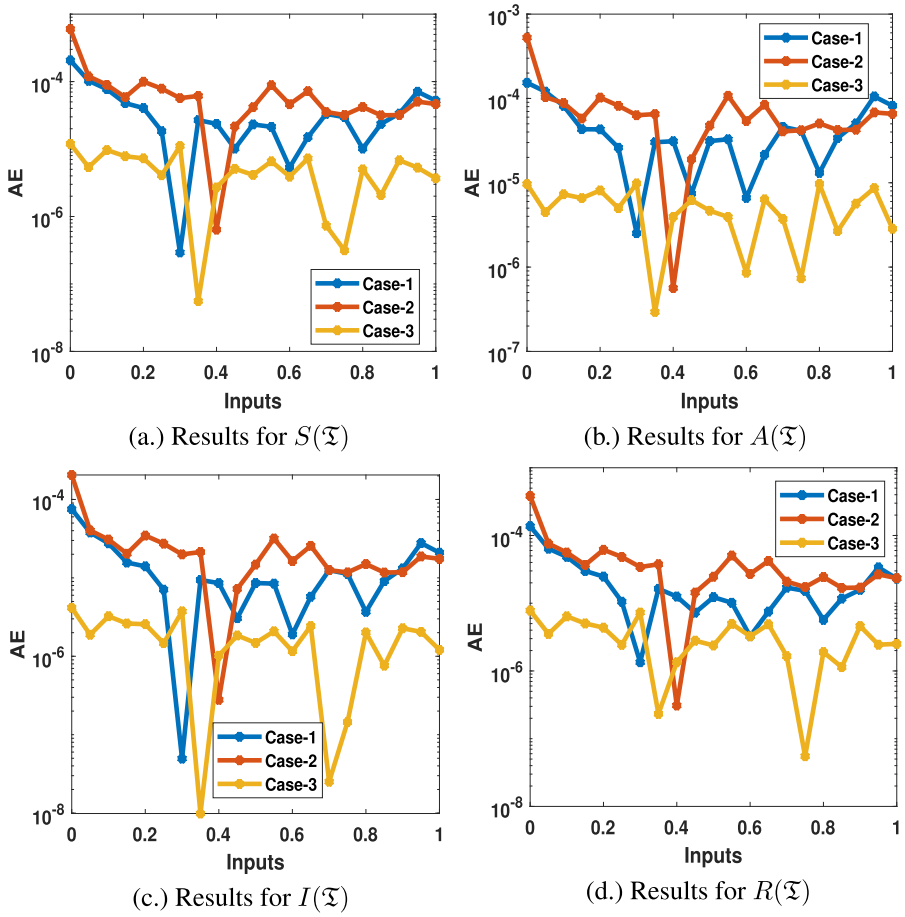


FIGURE 8. AE founded upon a FO-SAIR based system.

performances, utilizing STs, regression, correlation, EHs, as well as MSE. The correspondence between reference and actual results shows how accurate L-MBNNs relyed upon FO-SAIR-relyed differential system are. The stability and dependability of the recommended L-MBNNs serve as proof of the scheme's effectiveness.

In future, the proposed computing platform L-MBNNs could be used for explore of numerical measured results of the longer-wave, and fluid dynamics [35], [36], [37], [38]. Additionally, although the FO-SAIR model is straightforward to build, its application may aid in evaluating the dynamic activity of virus infections in real networks. Parameter impact is simple to collect, as are tools for establishing protocols to mitigate viral harm.

AUTHOR CONTRIBUTIONS STATEMENT

Sakda Noinang and Zulqurnain Sabir Conceptualization, Sakda Noinang, Wajaree Weera, and Maham Munawar formal analysis, Wajaree Weera funding acquisition, Muhammad Asif Zahoor Raja, and Thongchai Botmart Investigation, Sakda Noinang, Zulqurnain Sabir and Wajaree Weera Methodology, Maham Munawar and Zulqurnain Sabir Software, Thongchai Botmart Supervision, Thongchai Botmart Validation, Wajaree Weera and Thongchai Botmart Visualization, Sakda Noinang, Zulqurnain Sabir, and Thongchai Botmart Writing-original draft, Sakda Noinang, Zulqurnain Sabir, and Thongchai Botmart Writing-review & editing. All authors have read and agreed to the published version of the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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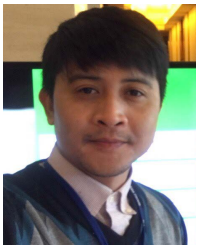

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