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Kottakkaran Sooppy Nisar (✉ n.sooppy@psau.edu.sa)

Prince Sattam bin Abdulaziz University

Muhammad Shoaib

COMSATS University Islamabad

Ghania Zubair

COMSATS University Islamabad

Muhammad Asif Zahoor Raja

National Yunlin University of Science and Technology

Ahmed Morsy

Prince Sattam bin Abdulaziz University

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The design of novel intelligent paradigms for future prediction smoking model with saturated occurrence rate

Muhammad Shoaib¹, Ghania Zubair¹, Muhammad Asif Zahoor Raja², Kottakkaran Sooppy Nisar^{3,*}, Ahmed Morsy³

¹Department of Mathematics, COMSATS University Islamabad, Attock Campus, Pakistan; dr.shoaib@cuiatk.edu.pk (M. Shoaib) sp20-rmt-002@cuiatk.edu.pk (Ghania Zubair)

²Future Technology Research Center, National Yunlin University of Science and Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, R.O.C; rajamaz@yuntech.edu.tw

³Department of Mathematics, College of Arts and Sciences, Prince Sattam bin Abdulaziz University, Wadi Aldawaser 11991, Saudi Arabia: n.sooppy@psau.edu.sa (KSN); a.morsy@psau.edu.sa (AM)

*Corresponding Author

Abstract: The approach of artificial neural network backpropagation with Levenberg Marquardt algorithm (LMA) and Bayesian Regularization algorithm (BRA) is used to analyze the smoking model in this study. We start by looking at a delayed smoking model wherein potential smokers be supposed to meet the logistic equation. As in manner of Delayed Differential Equations (DDEs), we analyze the dynamic characteristics of the developed framework and provide criteria regarding asymptotic stability of the system in steady condition. The model's Hopf bifurcation study is also addressed. The Adam numerical approach is used to build the reference dataset in Mathematica. The numerical and graphical results to the smoking problem is then interpreted using this dataset in MATLAB. The validity of applied techniques is validated using regression plots, MSE curves, and error histogram.

Keywords: Saturated incidence rate, artificial neural network, backpropagated, Levenberg-Marquardt algorithm, Bayesian Regularization algorithm.

Introduction:

Artificial Neural Network (ANN) is a computing technology that mimics the learning abilities of the human mind and its biological components. ANNs are made up of artificial neurons that are structured in layers and linked together by a connecting mechanism named as nodes or connections. To convert inputs into output, the ANN structure additionally includes biases assigned to neurons, weights connected to neuron linkages, and a transfer function with the presence of a bias quantity. By altering the numbers of the nodes, the neurons can be trained to do

a certain action, enabling the data route to be recognized. ANNs have been used to solve a variety of problems in industry and research, particularly in sectors where traditional modelling techniques have failed. Other engineering disciplines where the ANN model approach has been well welcomed include catalytic [1], analytical chemical [2], and energy fields including implementations of solar-based power systems [3] and cooling systems [4]. ANNs are a well-known and extremely strong numerical technique that have a wide range of uses in the realm of RF and microwaves [5]. Machine supervision [6], quantum physics [7], Genetic analysis [8], and combustion modelling [9] are only a few of the industrial and technological applications of ANN. The Thomas-Fermi model [10], COVID-19 [11], forecasting model [12], mosquito dispersal model [13], nonlinear reactive transport model [14], and dust density model [15] are examples of models that use stochastic numerical techniques.

Tobacco use is a worldwide major health issue. There are approximately 1000 million smokers on the planet, with that number anticipated to increase to almost 16000 million by 2025 [16]. Smoking is a behavior that involves burning a material and inhaling the ensuing smoke to be consumed and absorbed by the body. The most often used ingredient is dehydrated tobacco leaves folded onto a tiny chunk of rice paper to form a small, spherical cylinder known as a "cigarette" [17]. According to the WHO, tobacco causes around 6 million fatalities per year, with 600,000 of these happening in non-smokers as a result of passive smoking [18, 19]. Smoking is comparable to viral infections in that it spreads across the population. The number of ailments caused by smoking is steadily rising. For the first time, Castillo-Garsow et al. [20] designed a simplified quitting smoking model based on community-wide smoking behavior. The authors [21] concentrated on the control approach for the smoking problem by selecting the most effective programs. Additionally, certain smokers can return as a result of repeated interaction with other smokers, but others may quit smoking completely. On a smoking, Rahman et al. [22] have really been working. Khan et al. [23] used an iterative technique to study a biological modeling of smoking habit. Cancers of the larynx, oral cavity, lung, esophagus, pancreas, bladder, renal pelvis, abdomen, and cervix are all recognized or suspected to be caused by smoking. Cardiovascular disease, peripheral vascular disease, strokes, COPD and other breathing problems, and low-birth weight newborns are all linked to smoking [24]. Since the 2000s, there's been multiple efforts [25, 26] to quantitatively simulate the attempt to quit smoking.

Numerous scholars have examined time-delay differential equation (DDE) and in recent decades (see, for example, [27-30]), since they are extremely useful for modelling a broad number of scenarios in traditional fields like engineering and science, as well as relatively new fields like transmission of infection, clinical science, optimized drug rehabilitation, bio-economics, farming, financial management, insurance, and protection of the environment. Many fields, including population trends [31], epidemiology [32], and computer systems [33, 34], have adopted DDE for investigation.

Formulation of Model:

For the purpose of developing the model, researchers choose a constant rate for potential smokers. The entire scenario is provided by

$$\begin{aligned}\frac{dP}{dt} &= \Lambda - \mu P - \beta PS, \\ \frac{dS}{dt} &= \beta PS - (\mu + \gamma)S, \\ \frac{dQ}{dt} &= \gamma S - \mu Q,\end{aligned}\tag{1}$$

In which potential smokers are denoted by $P(t)$, persistent chain smokers are $S(t)$ and quit smokers are $Q(t)$ at time t , where μ , γ and β are the natural death rate, quit rate of smoking and coefficient of transmission, respectively.

$$\frac{dN}{dt} = \Lambda - \mu N,\tag{2}$$

$N(t)$ denotes the total population size at time t .

$$N(t) = P(t) + S(t) + Q(t)$$

The solution to equation (2) is exact.

$$N(t) = \frac{\Lambda}{\mu} + \left(N_0 - \frac{\Lambda}{\mu} \right) e^{-\mu t},\tag{3}$$

with

$$N(0) = P(0) + S(0) + Q(0),$$

Also

$$P(0) \geq 0, \quad S(0) \geq 0, \quad Q(0) \geq 0 \Rightarrow P(t) \geq 0, \quad S(t) \geq 0, \quad Q(t) \geq 0.$$

So, the solution possesses the property of positivity.

For stable population.

$$N = \frac{\Lambda}{\mu}.$$

Solution Methodology:

In the present study, smoking model is examined by utilizing the AI techniques, and these techniques are Levenberg Marquardt algorithm (LMA) and Bayesian Regularization algorithm (BRA). This article shows the comparison of the results of both techniques. The reference dataset is generated in Mathematica by applying Adam numerical algorithm. The smoking problem's numerical and graphical results are then evaluated in MATLAB using this dataset. The dataset has 70% points for training, 15% for testing and the remaining 15% for validation. Regression plots, MSE curves, and the error histogram are used to verify the validity of the approaches used. Figure 1 shows the neural network for smoking model. Figure 2 is the flowchart of the entire problem and the application of the technique. Table 1 illustrates the values for the parameters used in differential equations of smoking model, whereas Table 2 and 3 depict the outcomes of LMA and BRA, respectively.

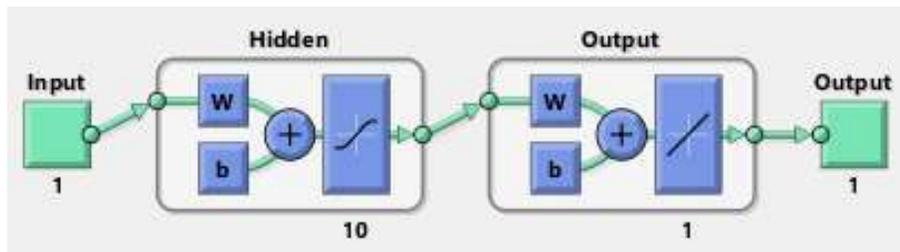


Figure1: Neural Network for Smoking Model

Table 1: Values of the parameters for Smoking Model

Parameters	Description	Parameter value
β	Transmission coefficient	0.005
Λ	Recruitment rate	10
γ	Quitting rate	0.3
K	Caring capacity	0.03
μ	Natural death rate	0.02
N	Growth rate	1.00

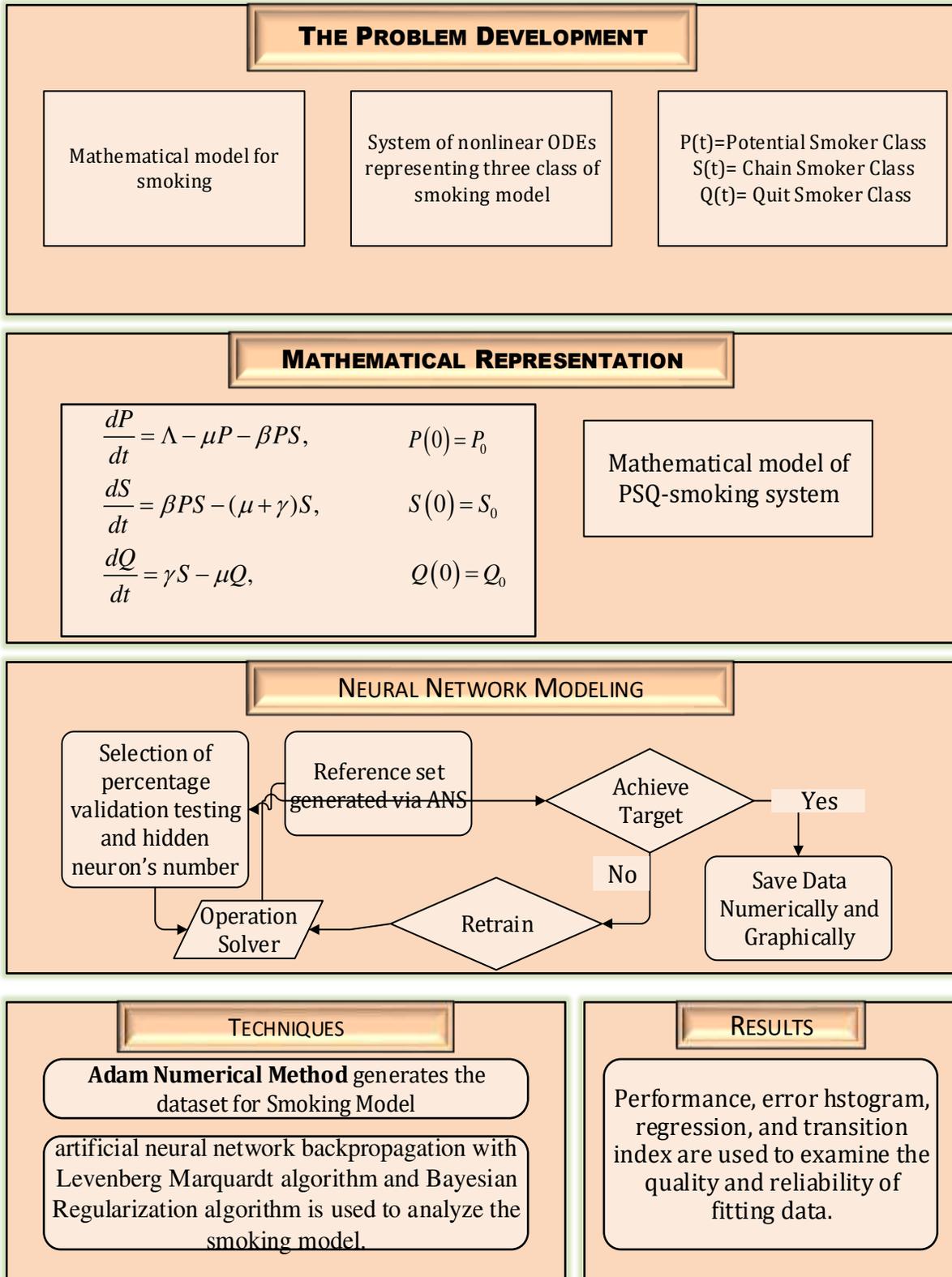


Figure 2: Flow chart of smoking model problem

Discussion and Conclusion:

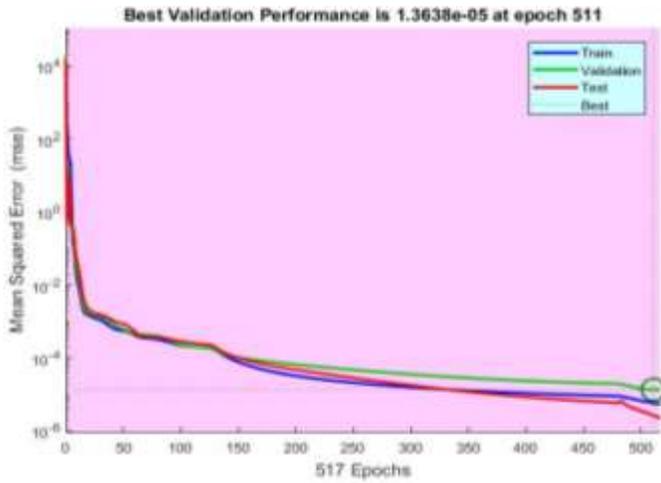
In this paper, the smoking model is analyzed using an artificial neural network backpropagation approach with the Levenberg Marquardt algorithm (LMA) and the Bayesian Regularization algorithm (BRA). Figure 3, 4 and 5 depict the resulting plots for $P(t)$, $S(t)$ and $Q(t)$, respectively. These resulting plots are performance plot, training state, error histogram, fitness and regression plot. These plots give the information about Mu, gradient, epochs, error and time for LMA and BRA. The MSE reflects the difference among simulation and observation; the less the MSE, the greater the performance. The Mu and gradient values related to epoch indicate whether convergence is slower or rapid; as epoch grows, the gradient and Mu values fall, indicating that convergence is quick. The error among anticipated and target values after training a neural network is represented by the histogram, which indicates the technique's dependability. Bins are 20 vertical bars included within every histogram. The zero error line, which is vertically red, signifies that the data is evenly distributed between positive and negative parts. The graph's bars show how much data is used for training, testing, and validation. The histogram shows that a lot of data is used for system training. Figure 6 and 7 show the comparison between the solution plot and absolute error plots of LMA and BRA, respectively. The absolute error for $P(t)$ is 10^{-5} to 10^{-2} and 10^{-6} to 10^{-2} for LMA and BRA, respectively, whereas for $S(t)$, the absolute error is 10^{-5} to 10^{-2} and 10^{-5} to 10^{-3} for LMA and BRA, respectively. In case of $Q(t)$, the value of AE lies between 10^{-4} to 10^{-1} and 10^{-5} to 10^{-3} for LMA and BRA, respectively.

Table 2: Outcomes of LMA for Smoking model

Case	MSE			Performance	Grad	Mu	Epochs	Time
	Training	Validation	Testing					
$P(t)$	5.80E-06	1.36E-05	2.66E-06	5.53E-06	0.171	1.00E-06	517	1s
$S(t)$	1.74E-05	1.90E-05	2.42E-05	1.63E-05	0.386	1.00E-05	95	<1s
$Q(t)$	2.90E-05	3.23E-05	7.44E-05	2.59E-05	0.0898	1.00E-05	416	<1s

Table 3: Outcomes of BRA for Smoking model

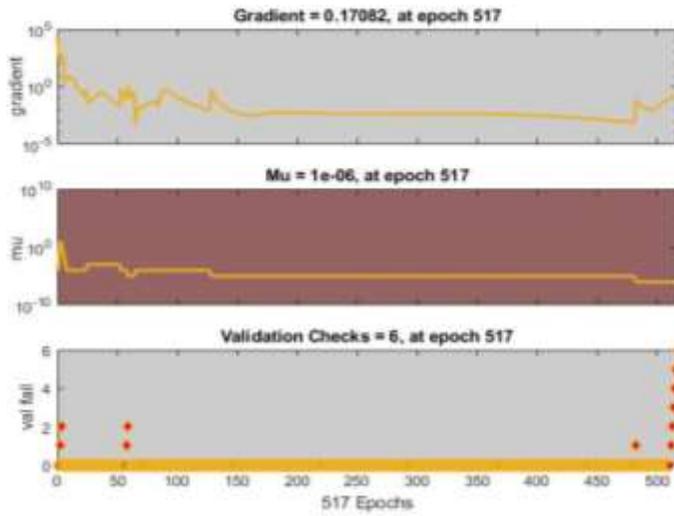
Case	MSE			Performance	Grad	Mu	Epochs	Time
	Training	Validation	Testing					
$P(t)$	7.09E-07	0.00E-0	1.94E-06	7.10E-07	5.05E-08	0.500	812	2s
$S(t)$	2.53E-08	0.00E-0	4.49E-08	2.53E-08	0.000518	500	1000	2s
$Q(t)$	2.56E-07	0.00E-0	4.12E-07	2.57E-07	7.47E-08	5.00	527	1s



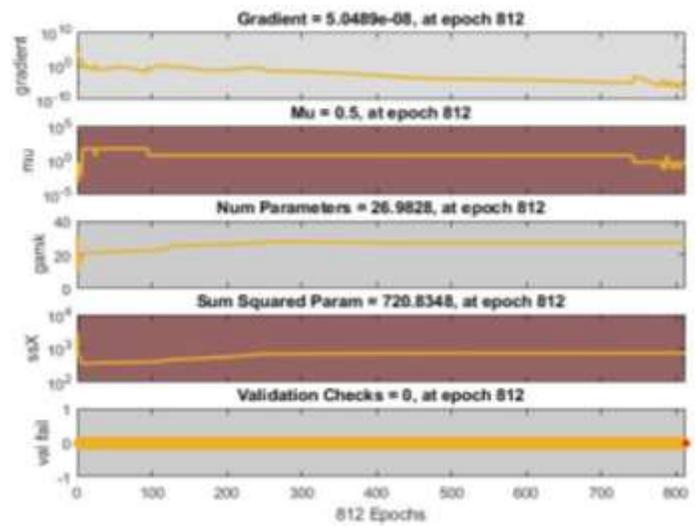
LMA: Performance for $P(t)$



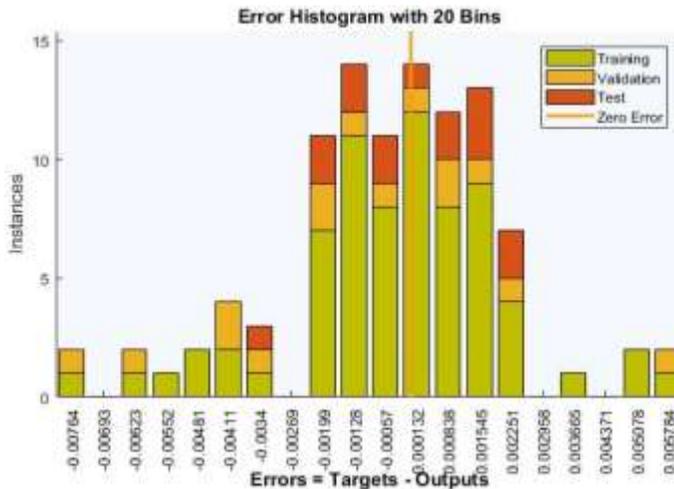
BRA: Performance for $P(t)$



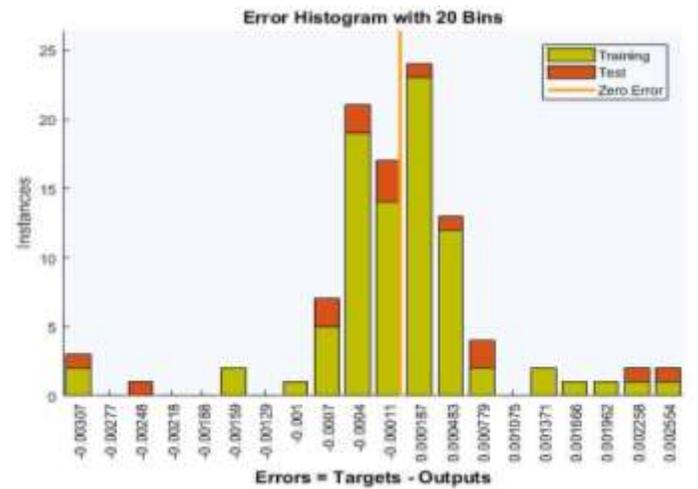
LMA: Training State for $P(t)$



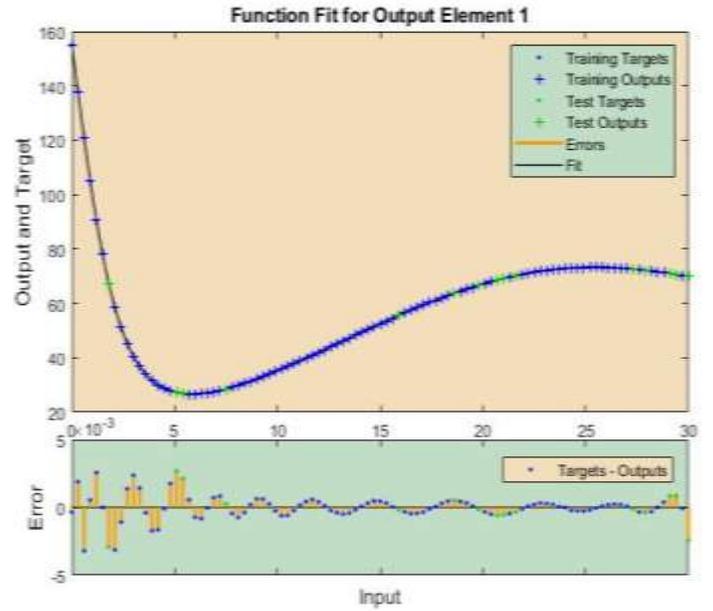
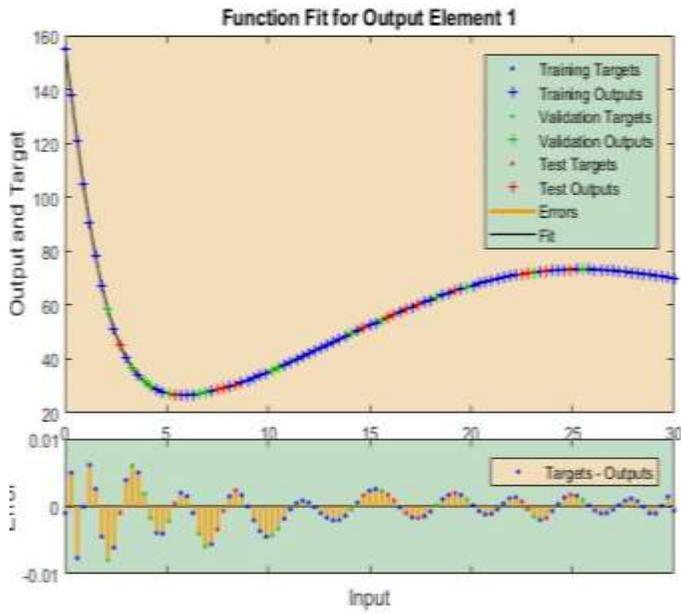
BRA: Training State for $P(t)$



LMA: Error Histogram for $P(t)$

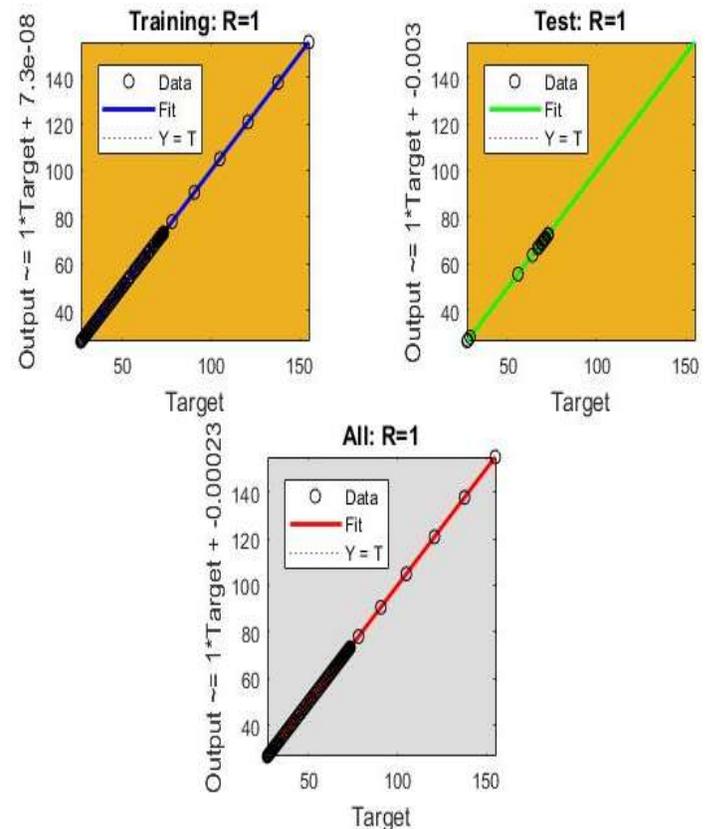
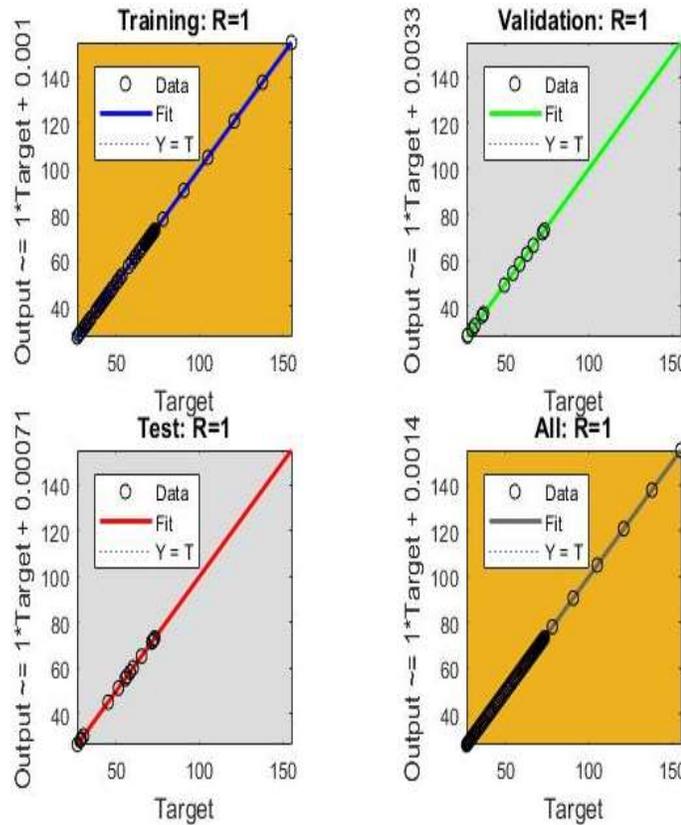


BRA: Error Histogram for $P(t)$



LMA: Fitness for $P(t)$

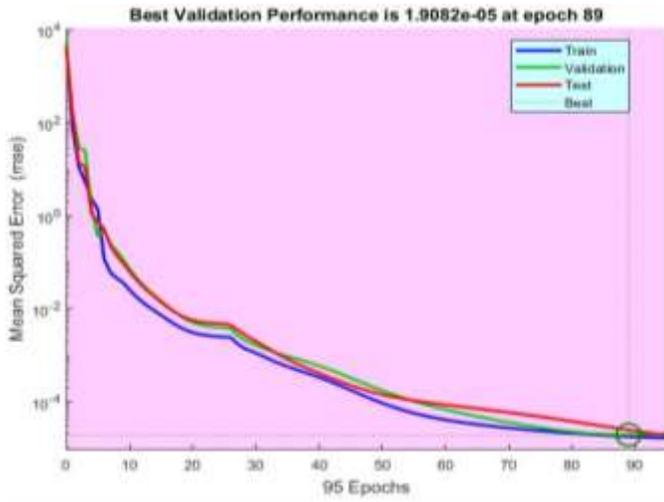
BRA: Fitness for $P(t)$



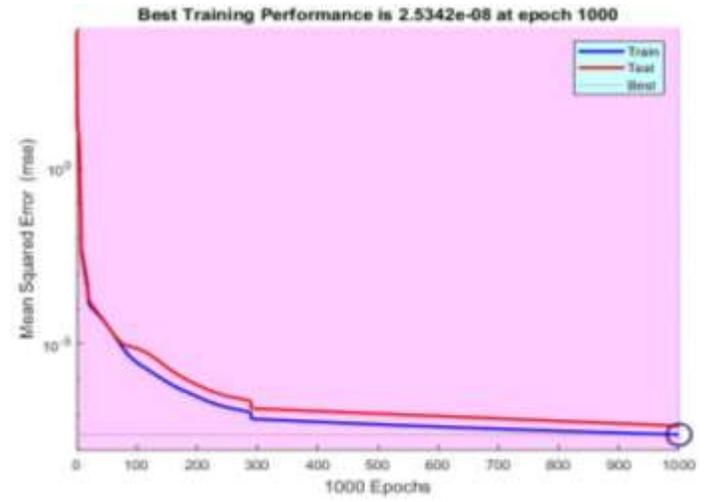
LMA: Regression for $P(t)$

BRA: Regression for $P(t)$

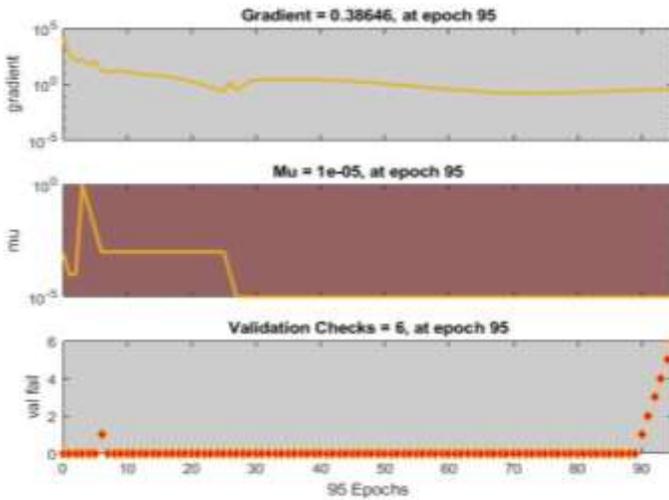
Figure 3: Comparison of resulting plots of LMA and BRA for $P(t)$.



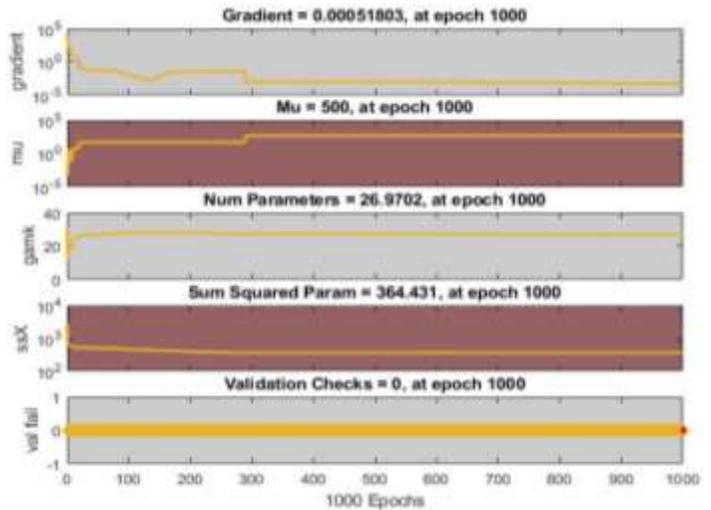
LMA: Performance for $S(t)$



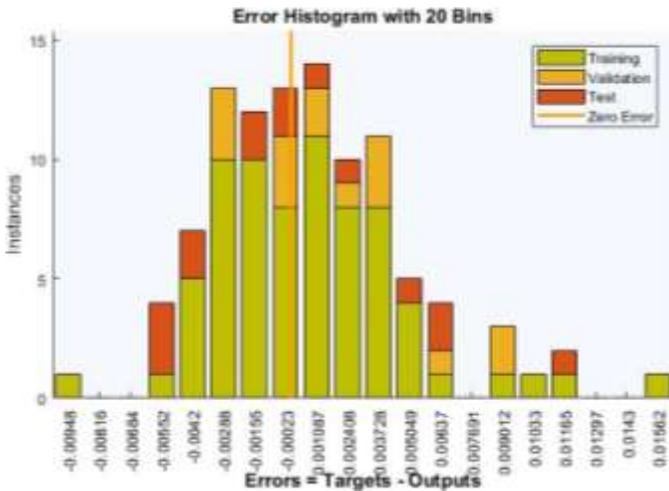
BRA: Performance for $S(t)$



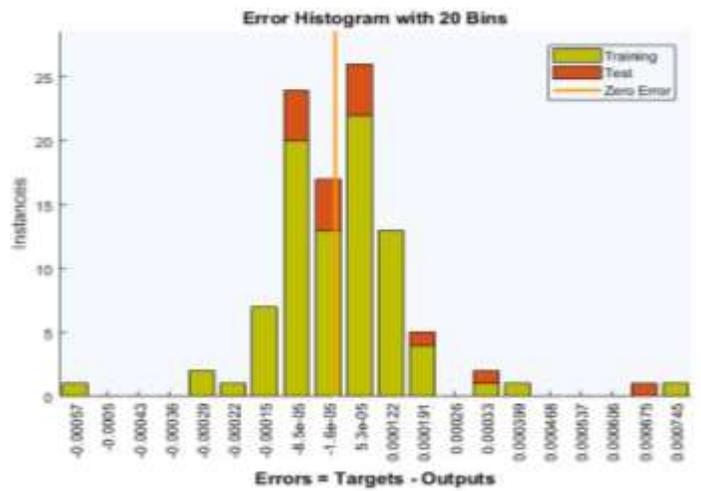
LMA: Training State for $S(t)$



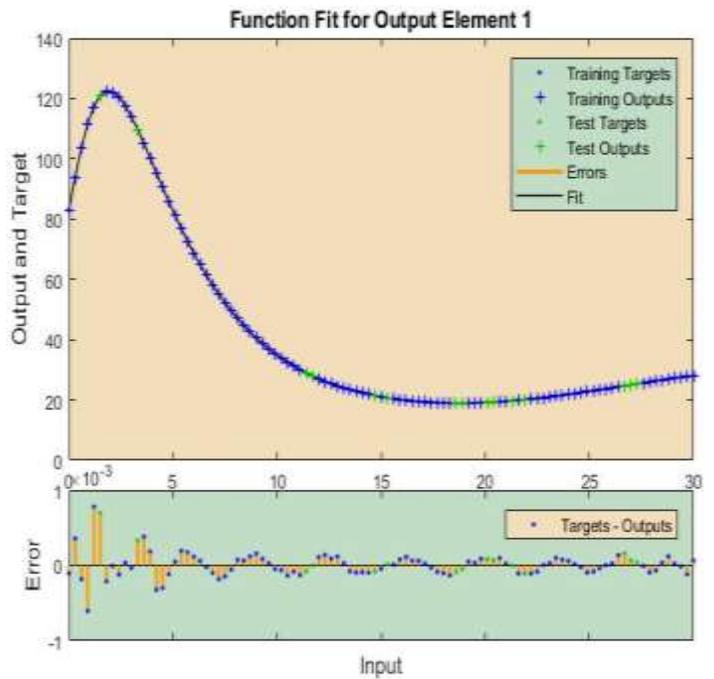
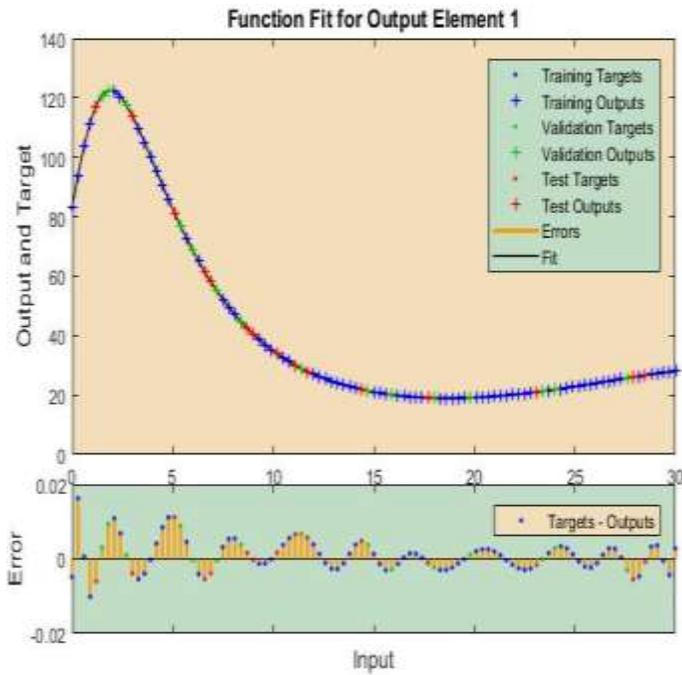
BRA: Training State for $S(t)$



LMA: Error Histogram for $S(t)$

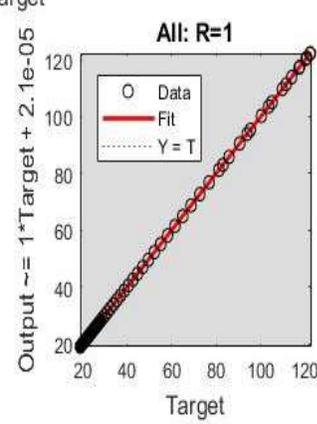
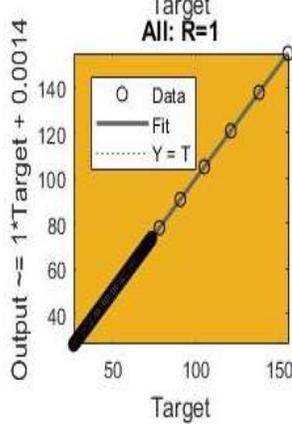
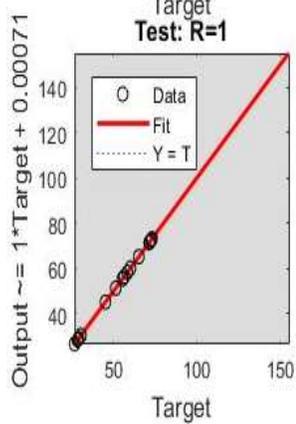
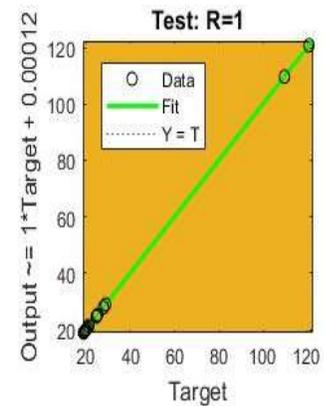
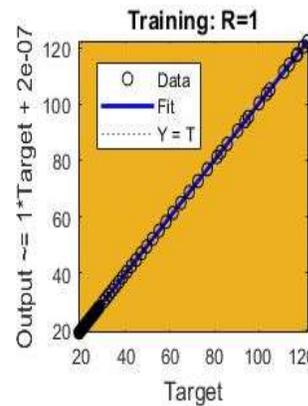
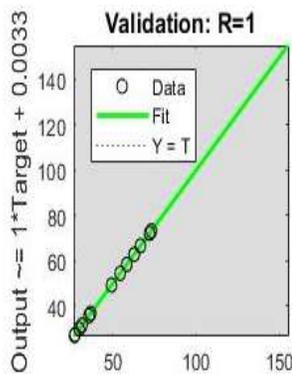
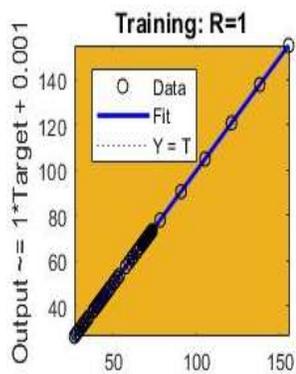


BRA: Error Histogram for $S(t)$



LMA: Fitness for $S(t)$

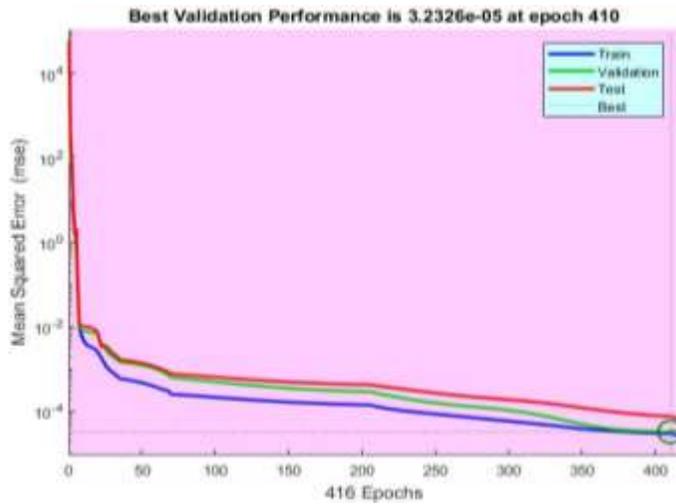
BRA: Fitness for $S(t)$



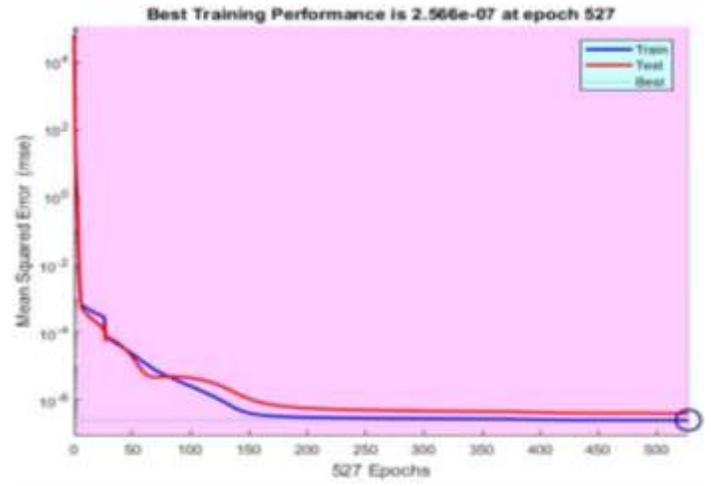
LMA: Regression for $S(t)$

BRA: Regression for $S(t)$

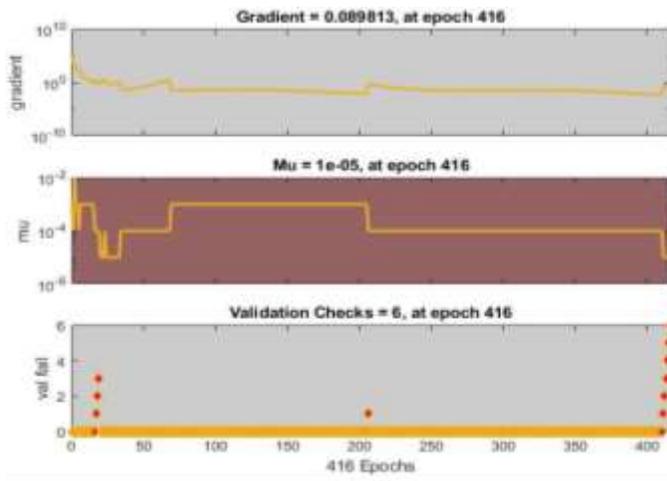
Figure 4: Comparison of resulting plots of LMA and BRA for $S(t)$.



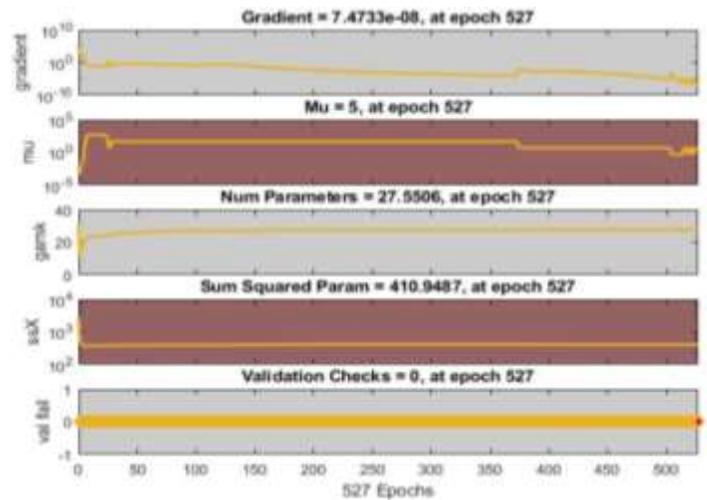
LMA: Performance for $Q(t)$



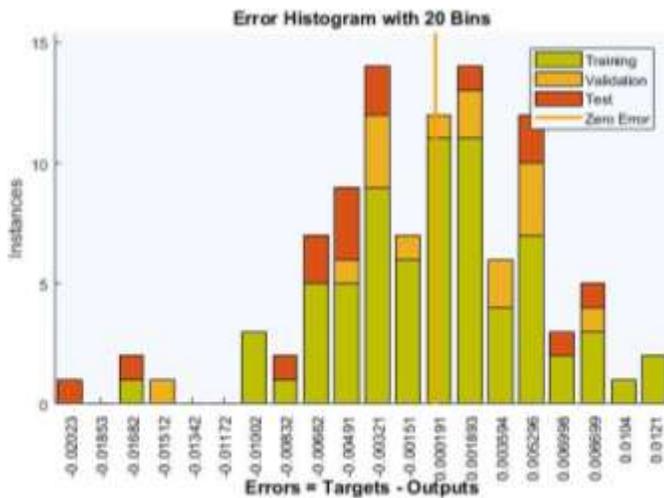
BRA: Performance for $Q(t)$



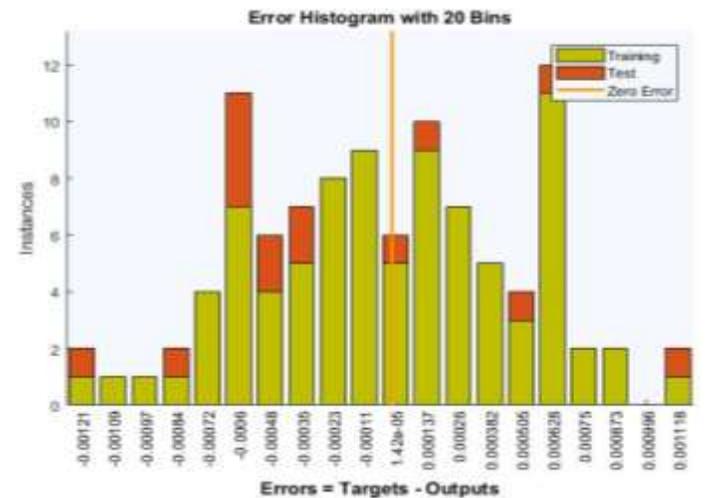
LMA: Training State for $Q(t)$



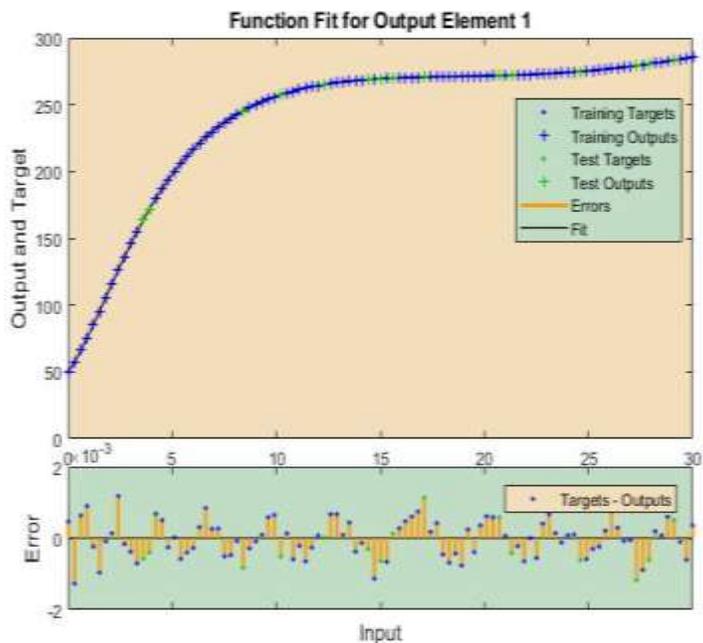
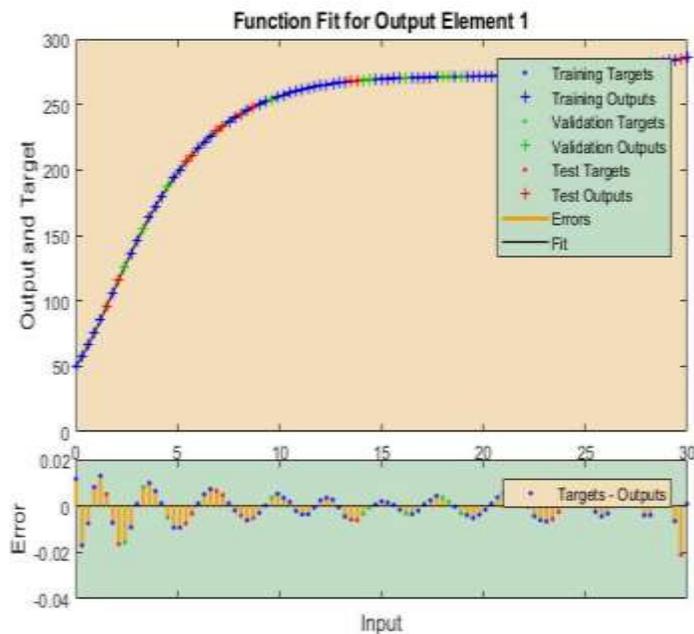
BRA: Training State for $Q(t)$



LMA: Error Histogram for $Q(t)$

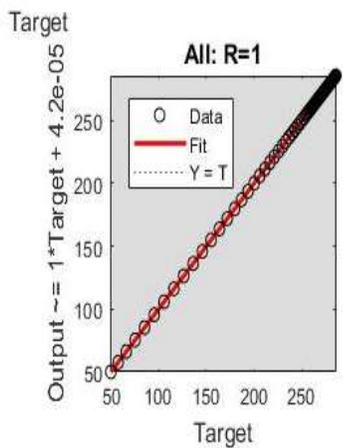
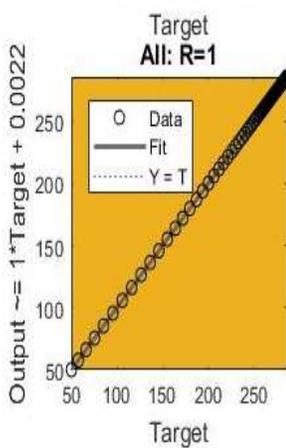
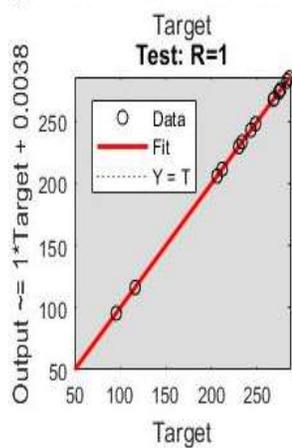
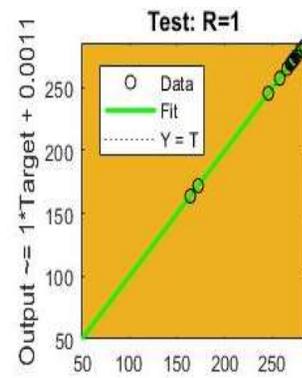
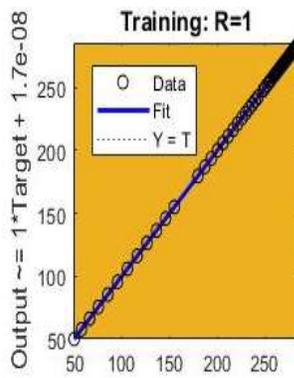
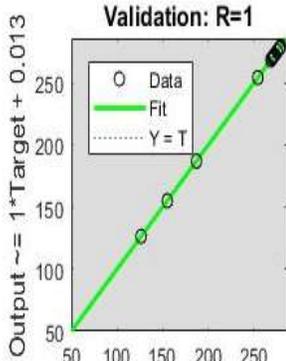
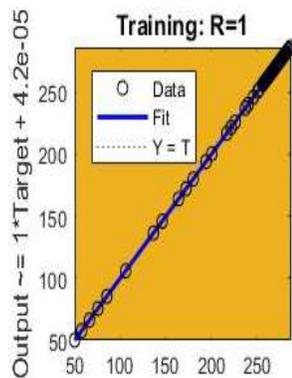


BRA: Error Histogram for $Q(t)$



LMA: Fitness for $Q(t)$

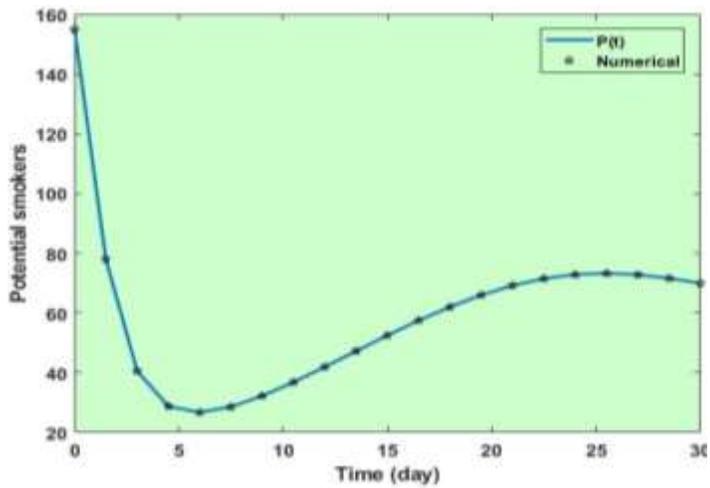
BRA: Fitness for $Q(t)$



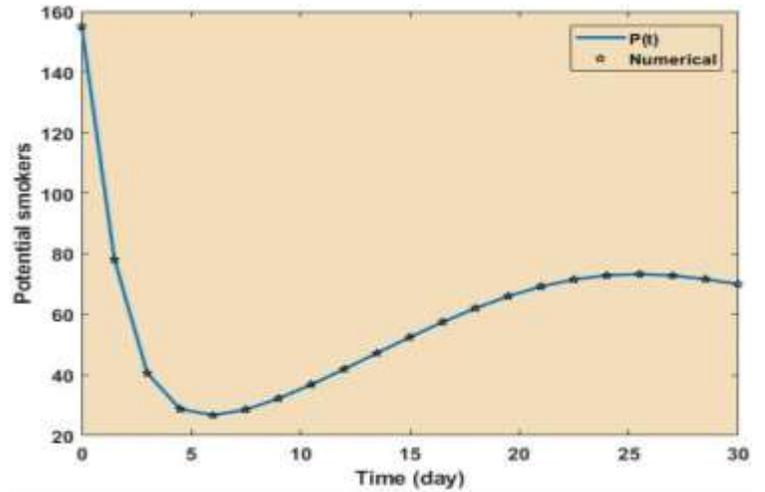
LMA: Regression for $Q(t)$

BRA: Regression for $Q(t)$

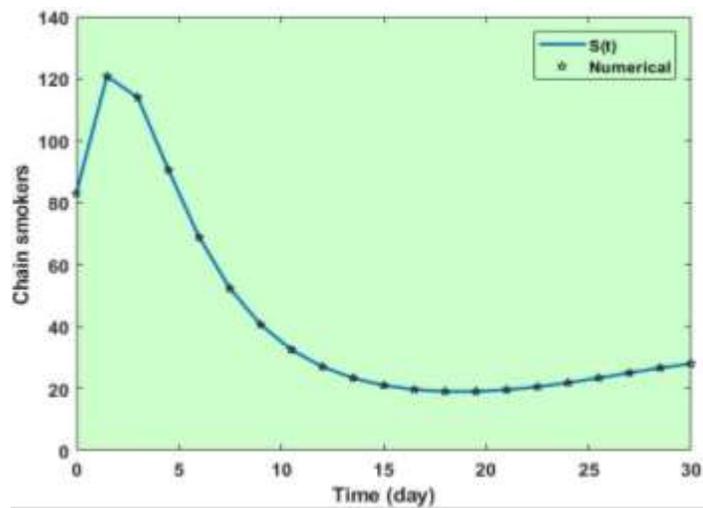
Figure 5: Comparison of resulting plots of LMA and BRA for $Q(t)$.



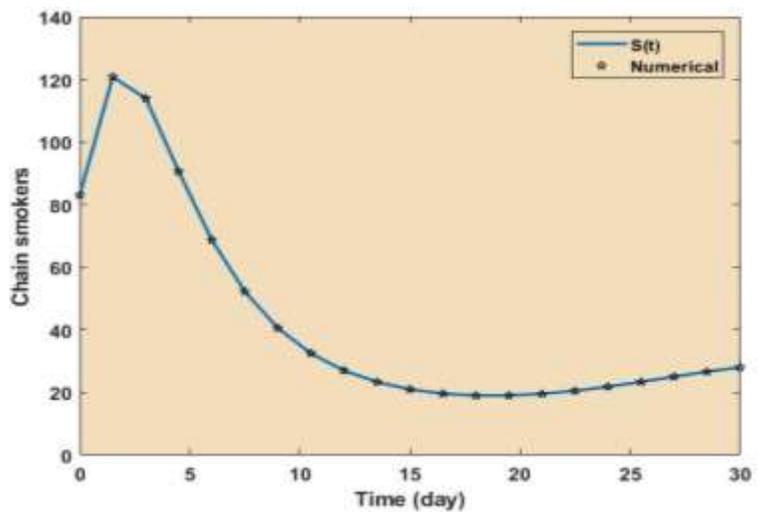
LMA: Solution plot for $P(t)$



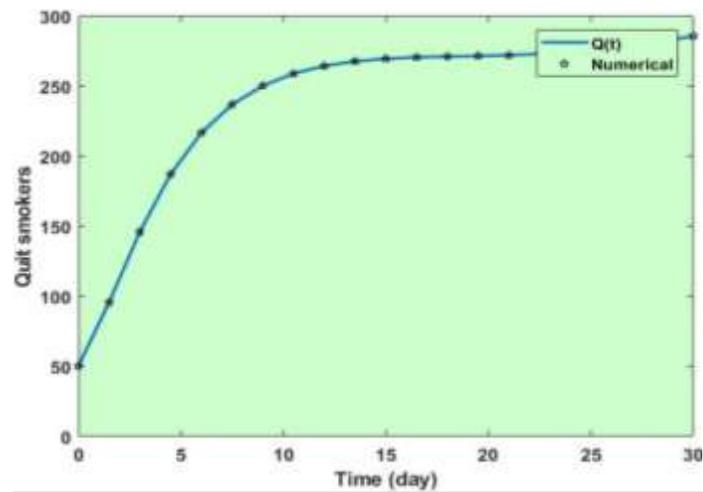
BRA: Solution plot for $P(t)$



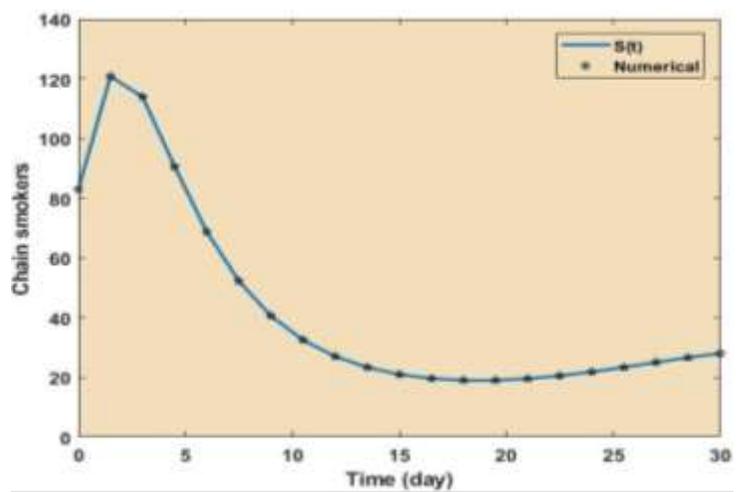
LMA: Solution plot for $S(t)$



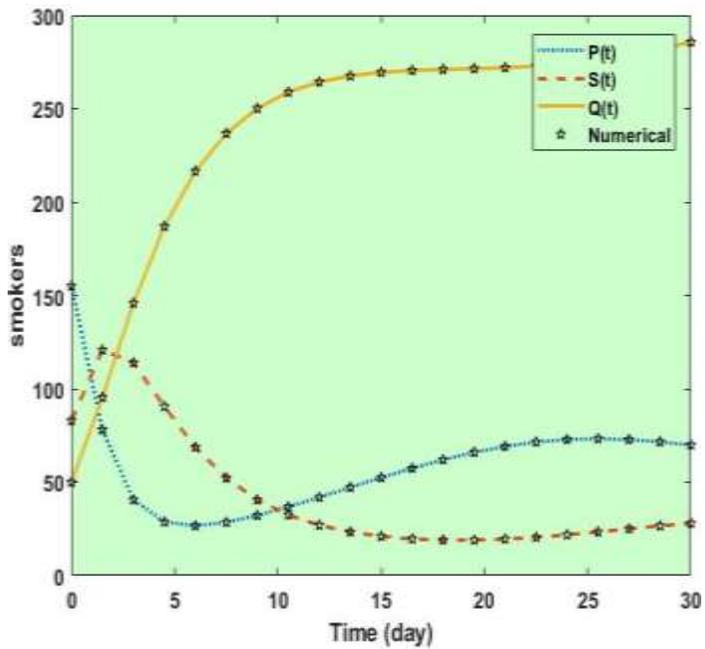
BRA: Solution plot for $S(t)$



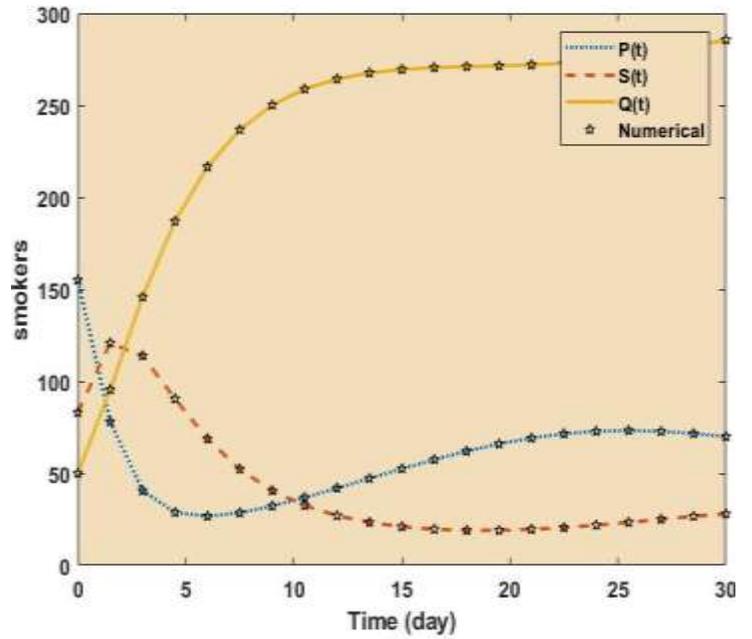
LMA: Solution plot for $Q(t)$



BRA: Solution plot for $Q(t)$

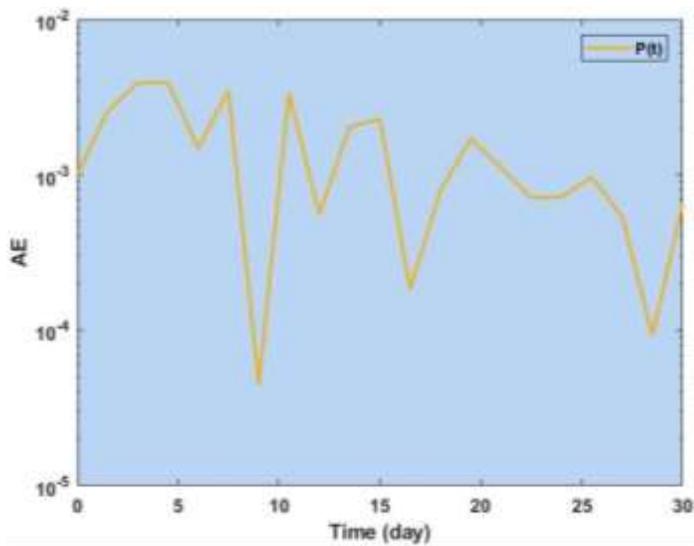


LMA: $P(t)$, $S(t)$, $Q(t)$

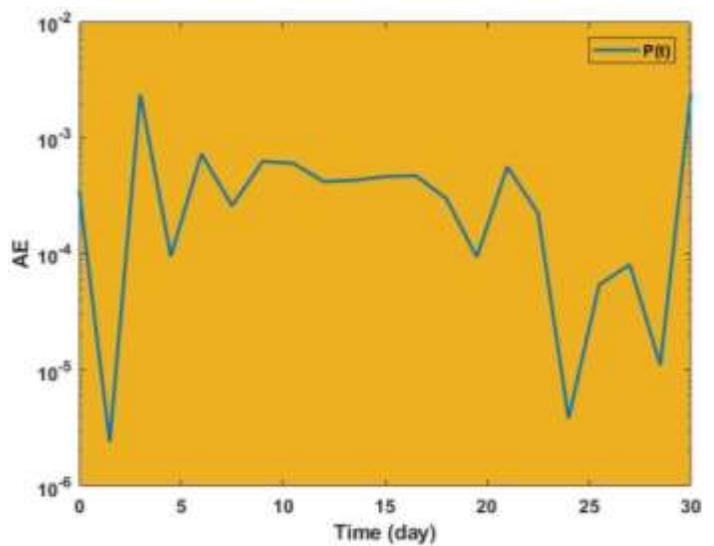


BRA: $P(t)$, $S(t)$, $Q(t)$

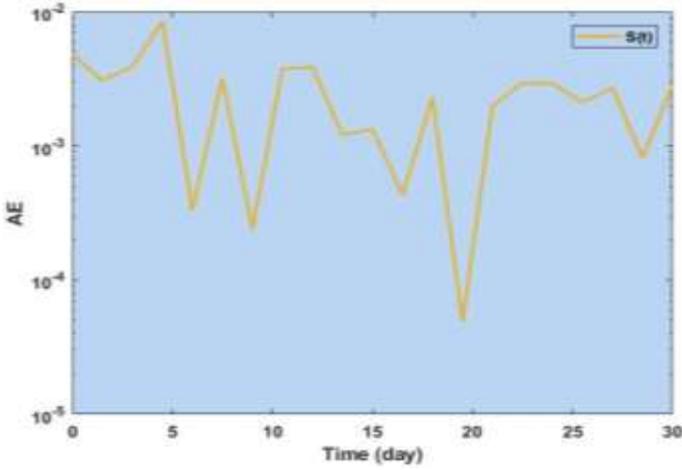
Figure 6: Comparison of solution plots of LMA and BRA.



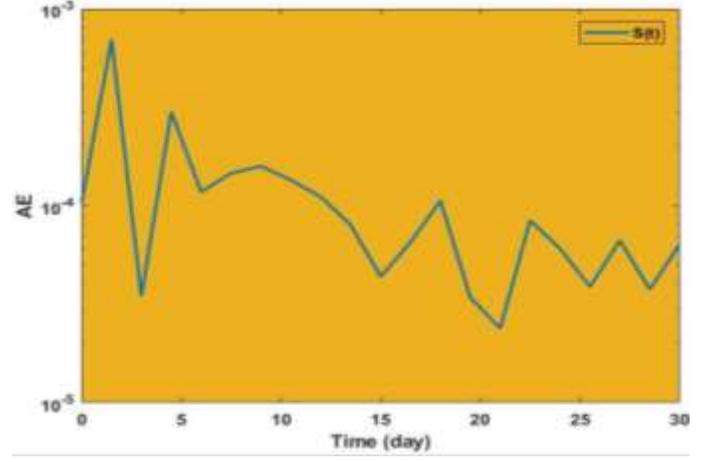
LMA: AE plot for $P(t)$



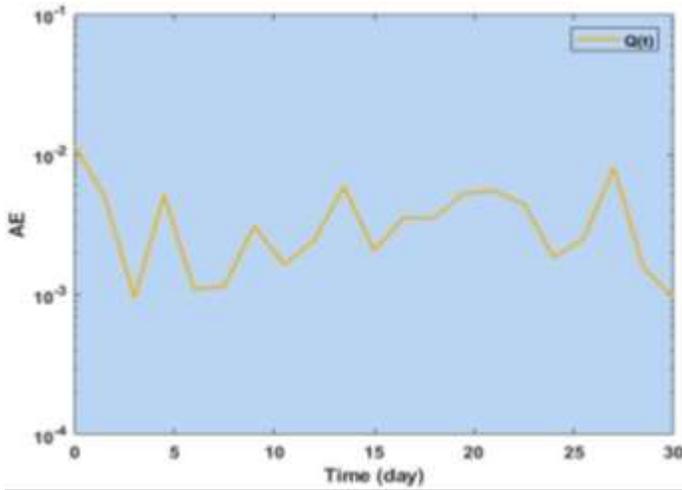
BRA: AE plot for $P(t)$



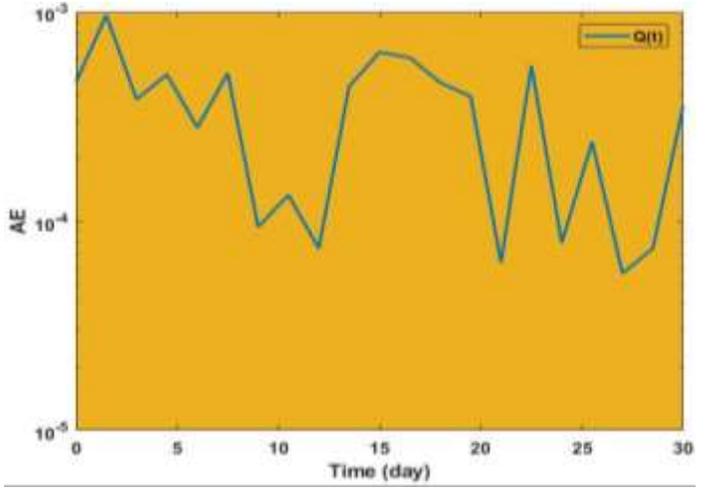
LMA: AE plot for $S(t)$



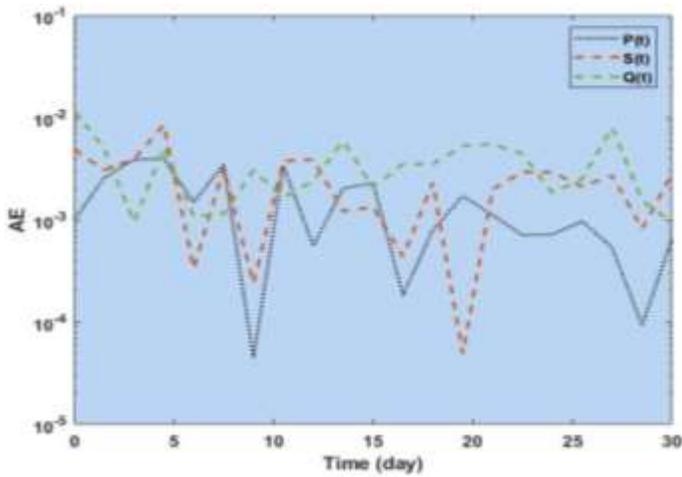
BRA: AE plot for $S(t)$



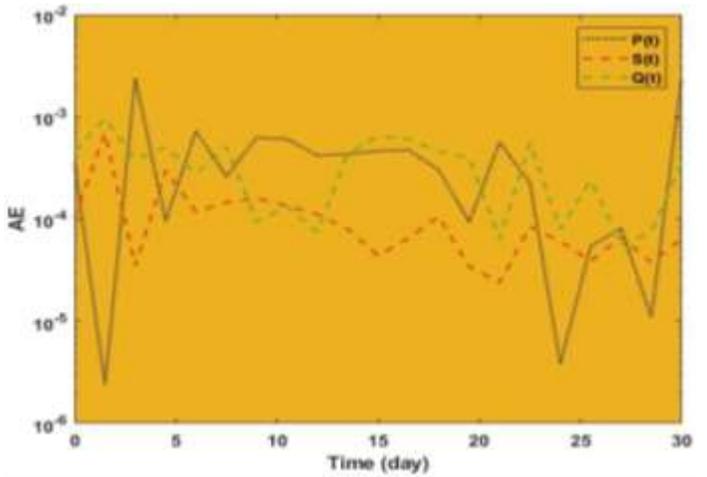
LMA: AE plot for $Q(t)$



BRA: AE plot for $Q(t)$



LMA: $P(t)$, $S(t)$, $Q(t)$



BRA: $P(t)$, $S(t)$, $Q(t)$

Figure 7: Comparison of absolute error plots of LMA and BRA.

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Conceptualization: MS, MAZR, KSN; Formal analysis: GZ, KSN; Investigation: MS, MAZR; Software: MS, GZ, KSN; Validation: MAZR; Writing—original draft: MS, GZ, KSN, MAZR, AM. All the authors read and approved the final manuscript.

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