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Respiratory Diseases Prediction from a Novel Chaotic System

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ABSTRACT

Pandemics can have a significant impact on international health systems. Researchers have found that there is a correlation between weather conditions and respiratory diseases. This paper focuses on the non-linear analysis of respiratory diseases and their relationship to weather conditions. Chaos events may appear random, but they may actually have underlying patterns. Edward Lorenz referred to this phenomenon in the context of weather conditions as the butterfly effect. This inspired us to define a chaotic system that could capture the properties of respiratory diseases. The chaotic analysis was performed and was related to the difference in the daily number of cases received from real data. Stability analysis was conducted to determine the stability of the system and it was found that the new chaotic system was unstable. Lyapunov exponent analysis was performed and found that the new chaotic system had Lyapunov exponents of (+, 0, -, -). A dynamic neural architecture for input-output modeling of nonlinear dynamic systems was developed to analyze the findings from the chaotic system and real data. A NARX network with inputs (maximum temperature, pressure, and humidity) and one output was used to to overcome any delay effects and analyze derived variables and real data (patients number). Upon solving the system equations, it was found that the correlation between the daily predicted number of patients and the solution of the new chaotic equation was 90.16%. In the future, this equation could be implemented in a real-time warning system for use by national health services.

KEYWORDS
Chaos
Chaotic systems
Respiratory
Diseases
Weather

INTRODUCTION

Seasonal climatic conditions and respiratory diseases such as influenza are believed to be related to each other. In fact, certain meteorological factors, such as temperature and relative humidity, and the incidence of some respiratory viruses have been hypothesized to have opposite relationships or those found in temperate regions. This may be because the majority of virus transmission takes place indoors, in air-conditioned spaces, which are cooler and less humid environments that are more conducive to airborne virus survival and transmission. In order to better plan hospital services for admissions, it is still necessary to comprehend the relationship between respiratory disorders, respiratory virus occurrence, and meteorological conditions in various countries. This is especially important now because viruses have just started to appear.

While investigating a meteorological problem, Lorenz (1963) stumbled upon a phenomenon that would become known as the "Butterfly Effect" (Kuhfittig and Davis 1990). Lorenz, a mathematician and meteorologist, was studying the behavior of weather systems using a simplified model of atmospheric convection. As he varied the initial conditions of his model, he noticed that small changes could lead to dramatically different outcomes in the long-term behavior of the system. This idea, that seemingly minor perturbations can have large and potentially unpredictable conse-

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quences, came to be known as the Butterfly Effect and has had a significant impact on the field of chaos theory (Gleick 1987; Holbrook 2003). The concept has been widely applied to a range of systems, including economics, biology, and even social networks, and has helped to shed light on the inherent unpredictability of certain types of complex systems.

In mathematics, chaos theory is a branch of study that investigates the behavior of dynamic systems that are highly sensitive to initial conditions. Non-linear systems that are chaotic or chaotic systems are sensitive to their initial conditions. The non-linearity systems have a specific case known as chaos. This line succinctly expresses the definition of chaos: chaos is the regularity of irregularity. Chaotic systems are complicated systems due to their nonlinear and deterministic nonlinear dynamical systems. Van der Pol and Van der Mark referred to the anarchy as noise. Dynamical systems that exhibit complicated behavior are considered chaotic systems (Van der Pol and Van Der Mark 1927; Kennedy 1995; Siegelmann and Fishman 1998; Akgül *et al.* 2022).

Chaotic systems exhibit the following characteristics: unpredictability in the time dimension, accuracy in the initial circumstances, an infinite number of distinct periodic oscillations, a broad power spectrum that resembles noise, and positive Lyapunov (Kia 2011; de la Fraga *et al.* 2012). Numerous chaotic systems, including Lorenz, Rikitake, Rossler, Sprott, Chen, Pehlivan and Akgul (Rikitake 1958; Rössler 1976; Sprott 1994; Chen and Ueta 1999; Akgul *et al.* 2016), have been introduced up until this point.

One way to study such systems is through the use of nonlinear differential equations, which are called "chaos equations." The solutions to these equations often exhibit complex and seemingly random behavior, giving rise to the term "chaos." However, despite their apparent randomness, the solutions of chaos equations are actually deterministic, meaning that they are completely determined by the initial conditions and the underlying equations. In other words, given the same initial conditions and equation, the system will always evolve in the same way. Following the development of the mathematical representation of chaos, it can be used in a wide range of fields, including engineering, computing, communications, biology and medicine, management and finance, consumer electronics (Ditto and Munakata 1995; Hilborn *et al.* 2000; Banerjee *et al.* 2012; Jun 2022; Yavari *et al.* 2022).

Respiratory diseases, such as asthma and chronic obstructive pulmonary disease (COPD), can be affected by weather conditions (Ayres *et al.* 2009; D'Amato *et al.* 2014, 2016; Mirsaeidi *et al.* 2016; Duan *et al.* 2020; Joshi *et al.* 2020). Cold air can cause the airways to narrow, leading to difficulty breathing and increased symptoms for those with respiratory conditions. Conversely, warm and humid air can also worsen respiratory symptoms, as it can make it more difficult for mucus to clear from the airways. Pollen and other allergens, which are more prevalent in certain weather conditions, can also trigger respiratory symptoms. It is important for individuals with respiratory conditions to pay attention to weather forecasts and take necessary precautions, such as carrying medications and wearing a mask, when conditions may worsen their symptoms. Cold air can cause the airways to narrow, leading to difficulty breathing and increased symptoms for those with respiratory conditions. Conversely, warm and humid air can also worsen respiratory symptoms, as it can make it more difficult for mucus to clear from the airways. Pollen and other allergens, which are more prevalent in certain weather conditions, can also trigger respiratory symptoms.

In this paper, we aim to investigate the feasibility of using the Lorenz equation and numerical methods, such as the Runge-Kutta method, to predict the number of patients with respiratory diseases based on weather data. To achieve this goal, a new chaotic equation will be derive and solved using the Runge-Kutta method. We will then use the results of our analysis to discuss the potential of this approach for predicting respiratory disease outbreaks and improving hospital planning. The significance of this research lies in the fact that it presents a novel chaotic system that can successfully predict the presence of respiratory diseases in patients, which has not been achieved in previous studies. This breakthrough holds the potential to greatly improve the diagnosis and treatment of respiratory conditions, as it allows for early identification of at-risk individuals and targeted interventions. As such, the findings of this study have the potential to significantly impact the field of healthcare and contribute to the betterment of public health.

The paper is divided into five sections, with the introduction being the first section. Section 2 will review the existing literature on the relationship between weather conditions and respiratory diseases, specifically influenza. Section 3 will cover chaos theory and the new chaotic equation that has been derived for this research. This section will describe the principles of chaos theory, the Lorenz equation, and the process of deriving the new chaotic equation. Section 4 will present the results of the study, including any analyses or simulations that were conducted using the new chaotic equation. The final section will provide conclusions based on the findings of the study and suggest directions for future research.

RELATED WORKS

A range of dynamic system behaviors are sensitive to initial conditions and can be unpredictable to some extent. In the early 20th century, Poincaré addressed the issue of weather forecasting. After Lorenz revisited this problem in the late 1960s, a significant portion of the scientific community began to focus on such phenomena, leading to the emergence of "Chaos Science" as a new branch of science. In 1963, Lorenz discovered new types of erratic oscillations while modeling fluid heat dissipation in the atmosphere to forecast weather patterns (Lorenz 1963). He gathered his previous solutions while taking a coffee break and returned to his computer to resolve the 12 ordinary differential equations he was using. When he returned, he found that the new solutions had reached a significantly different position than the previous ones. In other words, he discovered that the steady state exhibits new irregular oscillations with a significantly different appearance when the numerical integration is repeated with minimal variation in the initial conditions.

Lorenz, a meteorologist, was interested in mathematics and contributed to the development of the new field of chaos, a significant topic in the 20th century. He published his findings in a meteorology journal (Lorenz 1963). It took a decade for physicists and mathematicians to fully understand the significance of Lorenz's discovery. The Lorenz system has received significant attention and is considered the first example of how distributed systems can behave chaotically.

Following this, Lorenz developed equations for weather forecasting. In the field of chaos theory, numerous studies have been published in the last two decades about various systems, with Lorenz's system serving as a foundation for this research. This section therefore focuses on understanding the relationship between weather conditions and respiratory disease in order to develop a new chaotic system. In the next section, we will delve into the details of weather and respiratory diseases.

Weather Conditions and Respiratory Diseases

There are numerous published studies that describe the effect of weather conditions on respiratory infections, but no mathematical system has been developed to understand this association. These studies generally suggest that the relationship between infections and seasonal climate is causal. This was true to some extent when people lived and worked outdoors, with minimal protection from even the most extreme climatic conditions. However, the industrial revolution changed this. Many agricultural workers moved to factories and offices, and the widespread adoption of central heating and increasingly airtight, insulated buildings led to a further decoupling of daily and seasonal outdoor climate fluctuations. This separation is particularly noticeable in winter, when internal heating leads to a large deviation in the internal and external temperature and relative humidity (RH), but does not affect the absolute humidity (AH) (Quinn and Shaman 2017).

Nishimura et al. (2021) found that the average ambient temperature during daily working hours may have a stronger correlation with the number of patients transported by ambulance from outdoor sites than the daily average temperature or the daily highest temperature (Nishimura *et al.* 2021). The study results showed that patients transported from indoor environments are affected by previous environmental conditions for about 50 days, while those transported from outdoor sites are affected by a relatively shorter period of time (20 days), which may be due to heat adaptation. These findings provide a better understanding of the various factors that can lead to more accurate predictions of the number of heat-related patients based on weather forecasts.

A study by Lee et al. (2022) involving 525,579 individuals found that various weather and air quality factors affected the respiratory illnesses of people who visited emergency rooms (Lee *et al.* 2022). The majority of the patients with respiratory diseases had acute upper respiratory infections (J00-J06), influenza (J09-J11), and pneumonia (J12-J18), with PM10 temperature and steam pressure having the greatest effects. Pneumonia [J12–J18], acute upper respiratory infections [J00–J06], and chronic lower respiratory disorders [J40–J47] were the top three major causes of admission to the emergency room .

Bhimala et al. (2022) found that in different parts of India, specific humidity has a strong positive association, while maximum temperature has a negative correlation and minimum temperature has a positive correlation (Bhimala *et al.* 2022).

METHODOLOGY

This retrospective study aims to establish a chaotic equation that links weather and clinical data. To do so, the study first collected weather and patient data, and then applied Lorenz system to interpret the new variable. The stability of the new system was then evaluated using lyapunov analysis. To assess the correlation between the actual values and the results predicted by the new chaos equations, a NARX network was implemented to account for any delay effects and to predict the daily number of patients using real-time data.

Weather Data

Daily meteorological data, including maximum and minimum temperatures, relative humidity, pressure, and sunshine duration, were collected from the Meteorological Services Division. These parameters are illustrated in Figure 1.

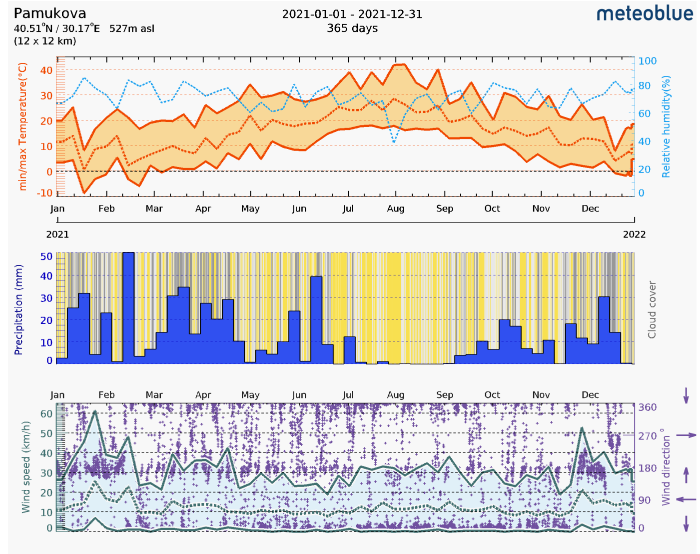

Figure 1 Weather data from Pamukova Region

Patient Data

The data for this study was collected from January 1, 2021 to December 31, 2021 with the ethical approval of Sakarya University (E-71522473-050.01.04-15185-157). The study group consisted of cases that occurred in the Pamukova District of Sakarya Province. A team of experienced medical professionals gathered the daily total of patients diagnosed with upper respiratory tract infections (J09-J18) from the Pamukova Family Medicine Center. Over the course of the study period, 10821 patients sought medical attention for upper respiratory illnesses.

Interpretation of New Variable

Edward Lorenz created the Lorenz system in 1963 as a more straightforward mathematical representation of atmospheric convection Lorenz (1963). The Lorenz chaotic system equations are well known and take the form of:

$$\begin{aligned} \dot{X} &= \alpha(Y - X) \\ \dot{Y} &= X(\beta - Z) - Y \\ \dot{Z} &= X * Y - \gamma Z \end{aligned} \tag{1}$$

With constant α = 10, β=28 and γ= 8/3. The initial conditions of the system are X(0) = 0, Y(0) = -1 and Z(0) = 0. We observe the chaotic behaviour, shown in Figure 2.

From this system, we assumed that there is an interpreted variable as a description of number of respiratory cases (w). This variable has the following:

1. Negative correlation with air pressure (Vitkina *et al.* 2019),
2. positive correlation with the average ambient temperature (Nishimura *et al.* 2021) and,
3. Negative correlation with the absolute humidity (Quinn and Shaman 2017).

The number of patients is also delayed due to the incubation period of diseases. Therefore, the variable is affected by the

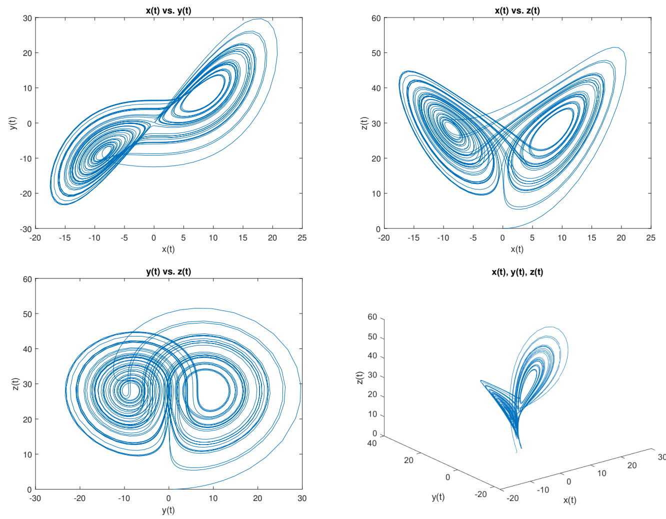

Figure 2 Phase portraits in the (x, y), (x, z), (y, z) and (x, y, z)

previous and current states. The newly found chaotic system are as follows:

$$\begin{aligned}
\dot{X} &= \alpha(Y - X), \\
\dot{Y} &= X(\beta - Z) - Y, \\
\dot{Z} &= X * Y - \gamma Z \\
\dot{W} &= X * Y - \delta(\alpha * W + Y) - \delta * Z
\end{aligned} \tag{2}$$

with constant α = 10, β=28, γ= 8/3, $\delta = 5$. The initial conditions of the system are X(0) = 10, Y(0) = -10, Z(0) = 25 and W(0)=0. The dynamic system simulation of the new chaotic system are shown in Figure 3.

System stability's analysis

Letting the system's derivatives equal to zero as:

$$\begin{aligned}
0 &= \alpha(Y - X), \\
0 &= X(\beta - Z) - Y, \\
0 &= X * Y - \gamma Z \\
0 &= X * Y - \delta(\alpha * W + Y) - \delta * Z
\end{aligned} \tag{3}$$

The equilibrium points are (0, 0.0000 - 8.4853i, 0.0000 + 8.4853i), (0, 0.0000 - 8.4853i, 0.0000 + 8.4853i), (0, -27, -27) and (0, -1.2600 - 0.8485i, -1.2600 + 0.8485i) and the eigenvalues of the first equilibrium point are: -50.0000 + 0.0000i, -2.6670 + 0.0000i, -1.2164 - 9.9045i, -9.7836 + 9.9045i; the first point is unstable. The eigenvalues of the second equilibrium point are: -50.0000 + 0.0000i, -2.6670 + 0.0000i, -1.2164 - 9.9045i and -9.7836 + 9.9045i; the second point is unstable. The eigenvalues of the third equilibrium point are: -50.0000, -2.6670, 8.2931 and -19.2931; the third point is unstable. The eigen values of the forth equilibrium point are: -50.0000 + 0.0000i, -2.6670 + 0.0000i, -4.9833 + 8.2108i, and -6.0167 - 8.2108i; the forth point is unstable.This analysis shows that the new system is unstable and may exhibit chaotic behavior, which can be confirmed by checking the Lyapunov exponents.

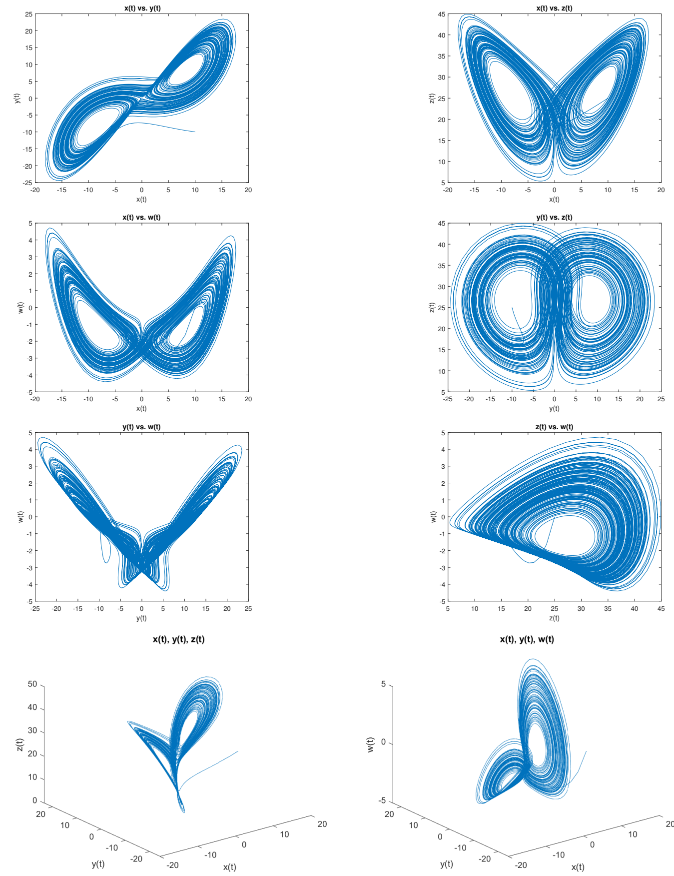

Figure 3 Phase portraits in the (x, y), (x, z), (x, w), (y, z), (y, w), (z, w), (x, y, z), and (x, y, w)

Lyapunov exponents analysis of Chaotic system

Lyapunov exponents are an important criterion in the analysis of the behavior of a dynamic system because they provide characteristic information about the system and serve as a measure of chaotic behavior (Abarbanel *et al.* 1991; Kinsner 2006; Aziz *et al.* 2021; Qiu *et al.* 2023). If the behavior of a dynamic system is sensitive to initial conditions, then as time progresses, orbits close to each other in the phase space will rapidly diverge. This indicates that the system is becoming dynamically unstable. However, it is often difficult to make this determination because most trajectories of the system are unknown. Nevertheless, it is possible to express the orbits that can be known.

Lyapunov superposition lambda gives a measure of the sensitivity to initial conditions and is defined as the average of the local separation degrees of neighboring curves within the phase space. If lambda is negative, different starting conditions tend to give the same output values, meaning that the development is not chaotic. If lambda is positive, different initial values give different output values, indicating that the movement is chaotic.
The fundamental characteristic of a chaotic system is its dependence on initial conditions. Even if the two different initial states are very close to each other, the orbits formed at these two points diverge from each other exponentially. Lyapunov exponents are used to measure the sensitive dependence of initial states in chaotic systems.

Lyapunov exponents are initially used to measure the distance between very small discrete trajectories. They are a generalization of the eigenvalues and characteristic multipliers of a periodic solution at an equilibrium point and are used to determine the steady-state stability of semiperiodic and chaotic solutions. A dynamic system is considered chaotic if its sum contains at least one positive Lyapunov exponent. The Lyapunov exponents of a chaotic trajectory have at least one positive lambda, which distinguishes a strange attractor from other types of steady-state behavior.

Nonlinear Autoregressive Network with Exogenous Inputs (NARX)

To analyze results from chaotic systems and real data, a popular dynamic neural design for input-output modeling of nonlinear dynamic systems, the NARX network, is implemented. The NARX network is a time-delayed feedforward neural network for time series estimation. In theory, NARX networks can be used in place of traditional recurrent networks with no computational cost and are at least as effective as Turing machines (Lin *et al.* 1996; Siegelmann *et al.* 1997; Diaconescu 2008). Therefore, they can be used to predict chaotic equations (Diaconescu 2008; Martínez-García *et al.* 2008).

In this study, a NARX network with 3 inputs (maximum temperature, pressure, and humidity) and one output (number of patients) was used to analyze derived variables and real data. The network had 10 hidden layers and an incubation period of 5 days was included to account for any variations due to delays. The final structure of the NARX network is depicted in Figure 4.

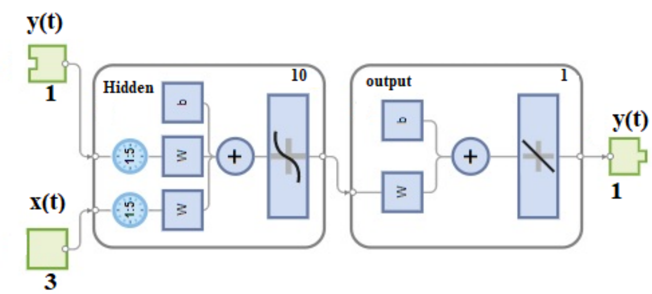

Figure 4 NARX Structure

RESULTS AND DISCUSSION

Results

Respiratory disorders, such as asthma and chronic obstructive pulmonary disease, are a major public health concern, as they can greatly impact an individual's quality of life and are a leading cause of morbidity and mortality worldwide. In this study, we aim to investigate the feasibility of using weather data to predict the prevalence of respiratory disorders. To accomplish this, we will utilize the Lorenz equation and numerical techniques, specifically the Runge-Kutta method, to derive and solve a new chaotic equation. The Runge-Kutta method is a numerical technique that is commonly used to solve differential equations. It is a widely used method that is known for its accuracy and stability, and has been applied to a variety of problems in science and engineering. In this study, we will use the Runge-Kutta method to solve the new chaotic equation that we will derive using the Lorenz equation and weather data.

Our objective is to use the Lorenz equation and the Runge-Kutta method to predict the prevalence of respiratory disorders based on weather data. By using these tools, we hope to gain a better understanding of the relationship between weather and respiratory disorders, and to develop more accurate and reliable methods for predicting the occurrence of these conditions. We believe that this research has the potential to significantly improve the management and treatment of respiratory disorders, and to ultimately improve the health and well-being of individuals affected by these conditions.

In order to give an example for the model detailed in the paper, a scenario is set with initial conditions and is expected to meet the actual data. In a three-dimensional system, the only possible case for Lyapunov exponents is the type (+, 0, -) to have chaotic behavior. For Lorenz Equation, they are $\lambda_1 > 0$, $\lambda_2 = 0$, *and* $\lambda_3 <0$. In a four-dimensional system, the possible cases for Lyapunov exponents are the type (+, +, 0, -) and (+, 0, -, -). If type (+, +, 0, -), $\lambda_1 > 0$, $\lambda_2 > 0$, $\lambda_3 = 0$, *and* $\lambda_4 < 0$, is called hyperchaos.

The Lyapunov exponents of the system were analyzed to investigate its chaotic behavior. The results of the analysis are shown below and depicted in Figure 5. The Lyapunov exponents of the system are (+, 0, -, -)."

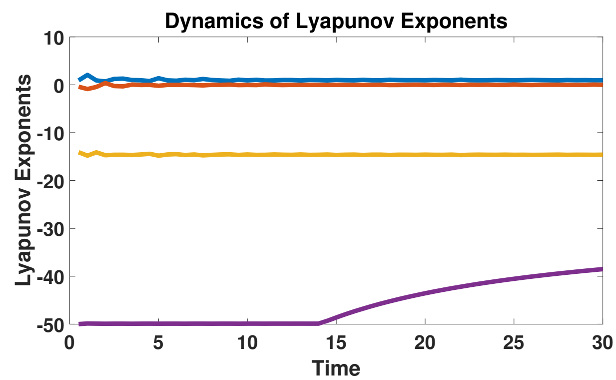

Figure 5 Lyapunov exponents

In this paper, we utilized the Lorenz equation and developed a new time series analysis, which is presented in Figure 6. However, as shown in Figure 7, the daily difference between the number of respiratory disease cases predicted by the chaotic equation and the actual number of cases is not similar to the difference between weather forecast and real weather data. This is due to the fact that the initial conditions for the chaotic equation and the weather data are not the same. To analyze the correlation between the real values and the results from the chaotic equation, we implemented a NARX network to account for any delay effects. The correlation between the number of cases predicted by the chaotic equation and the actual number of cases was found to be 90.16.

There is a well-established seasonality to the occurrence of influenza, with a marked peak in the colder winter months. However, in tropical regions, the seasonality of influenza is less well-defined, with detectable background activity throughout the year. In our study, we have developed a new chaotic model to better understand the patterns and underlying causes of respiratory diseases in these regions.

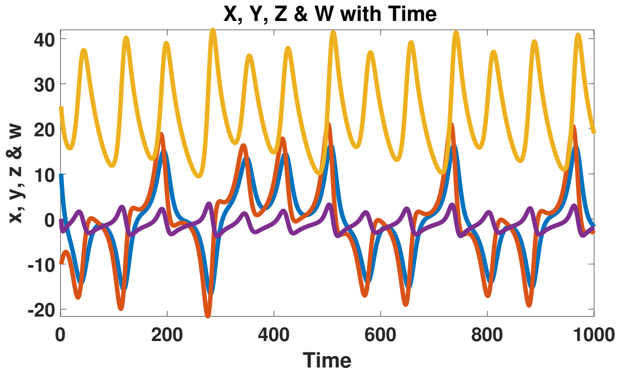

Figure 6 Time Series Analysis Results

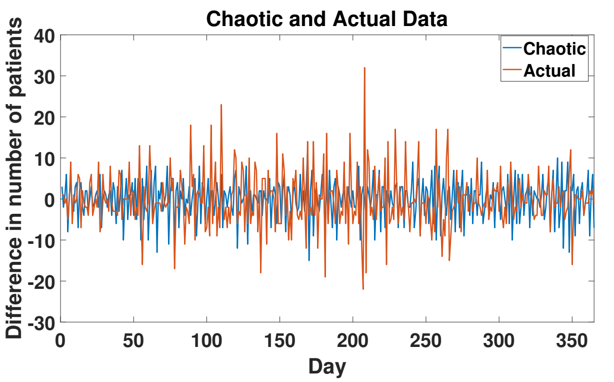

Figure 7 Actual and Equation Results

Discussion

This study used weather data to forecast the number of individuals who will have respiratory disease. This was achieved by developing a new chaos equation using patient data and weather predictions that have been gathered. The findings of this study agree with previous studies that have linked weather data to respiratory disease cases (Lee *et al.* 2022; Bhat *et al.* 2021).

The study of the relationship between weather patterns and respiratory illness led to the development of a novel chaotic system. According to the findings of this analysis, the system has Lyapunov exponents of (+, 0, -, -). A NARX network was then used to assess the created variables and real-world data, with a focus on counting the number of patients with respiratory illnesses. The daily projected patient count and the output of the new chaotic equation had a strong correlation of 90.16% after the chaotic system's equations were solved. As a result, the findings of this study are in line with those of other studies that have evaluated the effectiveness of time series in forecasting the occurrence of respiratory diseases (Shaman and Kohn 2009; Lee *et al.* 2022). This study reported a higher performance measure, with a correlation of 90.16% between real patient cases and predicted data.

Several methods have been identified in the literature for dealing with respiratory diseases. In a study (Lee *et al.* 2022), data from 525,579 participants was analyzed, and it was found that multiple variables of weather and air pollution influenced the respiratory diseases of patients who visited emergency departments. The majority of the patients with respiratory disease had acute upper respiratory infections. Similarly, another study (Xirasagar *et al.* 2006) found that the decline in temperature during colder months and the decrease in sunshine duration had a negative impact on respiratory diseases.

According to our research, predicting respiratory diseases from weather data could potentially be useful for hospital planning, as it could allow hospitals to anticipate increases in patient volume and adjust their staffing and resource allocation accordingly. It is important to have such a system that predict respiratory diseases from weather data.

CONCLUSIONS

There is a significant body of literature that explores the relationships between various fields, such as physics, mathematics, electrics, and electronics. These studies often involve the development and analysis of mathematical models that describe the behavior of chaotic systems. Scientists, engineers, and researchers may rely on these models in order to design and build new chaotic systems with complex and varied dynamic behaviors. However, the physical implementation of these models can be quite challenging due to the need to carefully consider and control initial conditions, as well as the impact of nonlinear effects. In other words, the real-world realization of chaotic systems based on these equations can be quite difficult and complex to achieve.

In this study, a new chaotic system was derived that investigates the connection between weather patterns and respiratory illness. To verify the chaotic behavior of the system, a Lyapunov analysis was performed. The results of this analysis indicated that the system had Lyapunov exponents of (+, 0, -, -). Next, the generated variables and real-world data were analyzed using a NARX network, specifically examining the number of patients suffering from respiratory illness. Upon resolving the equations of the chaotic system, it was found that there was a strong correlation of 90.16 between the daily anticipated patient count and the output of the new chaotic equation. It is anticipated that in the future, this model will be further refined and applied to different initial conditions depending on the local climate.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Availability of data and material

The data for this study was collected from January 1, 2021 to December 31, 2021 with the ethical approval of Sakarya University (E-71522473-050.01.04-15185-157). If you require raw data please contact corresponding author.

LITERATURE CITED

Abarbanel, H. D., R. Brown, and M. Kennel, 1991 Lyapunov exponents in chaotic systems: their importance and their evaluation using observed data. International Journal of Modern Physics B **5**: 1347–1375.

Akgül, A., E. E. Şahin, and F. Y. Şenol, 2022 Blockchain-based cryptocurrency price prediction with chaos theory, onchain analysis, sentiment analysis and fundamental-technical analysis. Chaos Theory and Applications **4**: 157 – 168.

Akgul, A., S. Hussain, and I. Pehlivan, 2016 A new three-dimensional chaotic system, its dynamical analysis and electronic circuit applications. Optik **127**: 7062–7071.

Ayres, J., B. Forsberg, I. Annesi-Maesano, R. Dey, K. Ebi, *et al.*, 2009 Climate change and respiratory disease: European respiratory society position statement. European Respiratory Journal **34**: 295–302.

Aziz, M. M. *et al.*, 2021 Stability, chaos diagnose and adaptive control of two dimensional discrete-time dynamical system. Open Access Library Journal **8**: 1.

Banerjee, S., L. Rondoni, and M. Mitra, 2012 *Applications of Chaos and Nonlinear Dynamics in Science and Engineering-Vol. 2*. Springer.

Bhat, G. S., N. Shankar, D. Kim, D. J. Song, S. Seo, *et al.*, 2021 Machine learning-based asthma risk prediction using iot and smartphone applications. IEEE Access **9**: 118708–118715.

Bhimala, K. R., G. K. Patra, R. Mopuri, and S. R. Mutheneni, 2022 Prediction of covid-19 cases using the weather integrated deep learning approach for india. Transboundary and Emerging Diseases **69**: 1349–1363.

Chen, G. and T. Ueta, 1999 Yet another chaotic attractor. International Journal of Bifurcation and chaos **9**: 1465–1466.

D'Amato, G., L. Cecchi, M. D'Amato, and I. Annesi-Maesano, 2014 Climate change and respiratory diseases.

D'Amato, G., C. Vitale, M. Lanza, A. Molino, and M. D'Amato, 2016 Climate change, air pollution, and allergic respiratory diseases: an update. Current opinion in allergy and clinical immunology **16**: 434–440.

de la Fraga, L. G., E. Tlelo-Cuautle, V. Carbajal-Gómez, and J. Munoz-Pacheco, 2012 On maximizing positive lyapunov exponents in a chaotic oscillator with heuristics. Revista mexicana de física **58**: 274–281.

Diaconescu, E., 2008 The use of narx neural networks to predict chaotic time series. Wseas Transactions on computer research **3**: 182–191.

Ditto, W. and T. Munakata, 1995 Principles and applications of chaotic systems. Communications of the ACM **38**: 96–102.

Duan, R.-R., K. Hao, and T. Yang, 2020 Air pollution and chronic obstructive pulmonary disease. Chronic diseases and translational medicine **6**: 260–269.

Gleick, J., 1987 The butterfly effect. Chaos: Making a New Science pp. 9–32.

Hilborn, R. C. *et al.*, 2000 *Chaos and nonlinear dynamics: an introduction for scientists and engineers*. Oxford University Press on Demand.

Holbrook, M. B., 2003 Adventures in complexity: An essay on dynamic open complex adaptive systems, butterfly effects, self-organizing order, coevolution, the ecological perspective, fitness landscapes, market spaces, emergent beauty at the edge of chaos, and all that jazz. Academy of Marketing Science Review **6**: 1–184.

Joshi, M., H. Goraya, A. Joshi, and T. Bartter, 2020 Climate change and respiratory diseases: a 2020 perspective. Current Opinion in Pulmonary Medicine **26**: 119–127.

Jun, M., 2022 Chaos theory and applications: the physical evidence, mechanism are important in chaotic systems. Chaos Theory and Applications **4**: 1–3.

Kennedy, M. P., 1995 Experimental chaos from autonomous electronic circuits. Philosophical Transactions of the Royal Society of London. Series A: Physical and Engineering Sciences **353**: 13–32.

Kia, B., 2011 Chaos computing: from theory to application. Technical report, Arizona State University.

Kinsner, W., 2006 Characterizing chaos through lyapunov metrics. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) **36**: 141–151.

Kuhfittig, P. K. and T. W. Davis, 1990 Predicting the unpredictable. Cost Engineering **32**: 7.

Lee, E. S., J.-Y. Kim, Y.-H. Yoon, S. B. Kim, H. Kahng, *et al.*, 2022 A machine learning-based study of the effects of air pollution and weather in respiratory disease patients visiting emergency departments. Emergency Medicine International **2022**.

Lin, T., B. G. Horne, P. Tino, and C. L. Giles, 1996 Learning long-term dependencies in narx recurrent neural networks. IEEE Transactions on Neural Networks **7**: 1329–1338.

Lorenz, E. N., 1963 Deterministic nonperiodic flow. Journal of atmospheric sciences **20**: 130–141.

Martínez-García, J. A., A. M. González-Zapata, E. J. Rechy-Ramírez, and E. Tlelo-Cuautle, 2008 On the prediction of chaotic time series using neural networks. Chaos Theory and Applications **4**: 94–103.

Mirsaeidi, M., H. Motahari, M. Taghizadeh Khamesi, A. Sharifi, M. Campos, *et al.*, 2016 Climate change and respiratory infections. Annals of the American Thoracic Society **13**: 1223–1230.

Nishimura, T., E. A. Rashed, S. Kodera, H. Shirakami, R. Kawaguchi, *et al.*, 2021 Social implementation and intervention with estimated morbidity of heat-related illnesses from weather data: A case study from nagoya city, japan. Sustainable Cities and Society **74**: 103203.

Qiu, H., X. Xu, Z. Jiang, K. Sun, and C. Cao, 2023 Dynamical behaviors, circuit design, and synchronization of a novel symmetric chaotic system with coexisting attractors. Scientific Reports **13**: 1893.

Quinn, A. and J. Shaman, 2017 Health symptoms in relation to temperature, humidity, and self-reported perceptions of climate in new york city residential environments. International journal of biometeorology **61**: 1209–1220.

Rikitake, T., 1958 Oscillations of a system of disk dynamos. In *Mathematical Proceedings of the Cambridge Philosophical Society*, volume 54, pp. 89–105, Cambridge University Press.

Rössler, O. E., 1976 An equation for continuous chaos. Physics Letters A **57**: 397–398.

Shaman, J. and M. Kohn, 2009 Absolute humidity modulates influenza survival, transmission, and seasonality. Proceedings of the National Academy of Sciences **106**: 3243–3248.

Siegelmann, H. T. and S. Fishman, 1998 Analog computation with dynamical systems. Physica D: Nonlinear Phenomena **120**: 214–235.

Siegelmann, H. T., B. G. Horne, and C. L. Giles, 1997 Computational capabilities of recurrent narx neural networks. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) **27**: 208–215.

Sprott, J. C., 1994 Some simple chaotic flows. Physical review E **50**: R647.

Van der Pol, B. and J. Van Der Mark, 1927 Frequency demultiplication. Nature **120**: 363–364.

Vitkina, T. I., L. V. Veremchuk, E. E. Mineeva, T. A. Gvozdenko, M. V. Antonyuk, *et al.*, 2019 The influence of weather and climate on patients with respiratory diseases in vladivostok as a global health implication. Journal of Environmental Health Science and Engineering **17**: 907–916.

Xirasagar, S., H.-C. Lin, and T.-C. Liu, 2006 Seasonality in pediatric asthma admissions: the role of climate and environmental factors. European journal of pediatrics **165**: 747–752.

Yavari, M., A. Nazemi, and M. Mortezaee, 2022 On chaos control of nonlinear fractional chaotic systems via a neural collocation optimization scheme and some applications. New Astronomy **94**: 101794.

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