iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: X Month of publication: October 2025

DOI: https://doi.org/10.22214/ijraset.2025.74615

www.ijraset.com

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Review on Designing Multiple Neural Network-Based Intelligent Computing Procedures for Solving the Anthrax Disease Model Used in Animal

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Abstract: The aim of this work is to provide the numerical representations of the anthrax disease model used in animals both in integer and fractional form by designing a soft computing platform based on multiple neural network procedures. The integer order form of the anthrax disease model used in animals will be discussed first and then the fractional order derivatives of the anthrax disease model used in animals are solve later to get more precise solutions of the model. The values of the fractional order will be taken between 0 and 1 in order to check, which results perform better either close to zero or one. The mathematical form of the anthrax disease model used in animals is categorized into four classes, named as susceptible, infected, recovered and vaccinated. The dataset is obtained through the explicit Runge-Kutta and Adams numerical technique, which is used to train the neural network procedures in order to reduce the mean square error by separating into training as 80%, testing 8% and substantiation 12%. The design of the supervised neural network procedures based on the Levenberg–Marquardt backpropagation scheme, Bayesian regularization approach and computational scale conjugate neural network solver is presented through the activation log- sigmoid function or radial basis functions. The process of supervised neural network is used with a single hidden layer structure and deep neural network construction using two or more hidden layers. The numbers of neurons will be selected by performing many tests in the hidden layer(s) for solving the anthrax disease model used in animals. The optimization is performed through the efficient and reliable Marquardt backpropagation, Bayesian regularization approach scale conjugate neural network procedures for the numerical performances of the mathematical anthrax disease system in animals. The exactness and accuracy of the designed solver is validated through the matching of the outcomes and negligible values of the absolute error that are performed around 10-05 to 10-08 for each case of the anthrax disease model used in animals. The correctness of the designed computational scale conjugate neural network has also observed through the optimal training performances, which are calculated around 10^{-10} to 10^{-12} for each case of the anthrax disease model used in animals. Furthermore, the statistical values in the form of error histogram, regression coefficient, and state transition enhance the reliability and stability of the designed computational scale conjugate neural network for presenting the numerical solutions of the anthrax disease model used in animals. The designed computational Marquardt backpropagation, Bayesian regularization and scale conjugate neural networks has never been tested before for presenting the numerical representations of the anthrax disease model used in animals.

Keywords: Anthrax disease; Neural network; fractional order; Single or multiple layers; Optimization schemes; Numerical solutions.

I. INTRODUCTION

Anthrax is a serious zoonotic disease which impacts animals all over the world and is frequently acknowledged to be lethal. It is created by the anthracis producing bacteria and mainly affects herbivorous organism such as goats, sheep, horses, and cattle, though it may additionally infect other animals [1]. Direct contact with diseased animals, germs in the ground, polluted feed, or liquid may transmit this infection. Because these microorganisms can survive for a considerable amount of time, anthrax poses a constant risk. Several medical treatments, such as digestive tract, cutaneous, septicemic, and respiratory anthrax, are present in an infection system determined by anthrax in livestock [2]. While gastric anthrax is caused by consuming tainted food or beverages, it also causes skin sores. The airways and septicemic anthrax are disturbed by respiratory anthrax, which contaminates the blood. fatigue, bloody release, appetite loss, fever , enlarged lymphocytes, and breathing issues are some of the indications. The operational treatment requires rapid evaluation based on test results and medical indications. In order to prevent anthrax outbreaks in wildlife populations, quarantine and immunization measures are vital.

Live spore-based vaccinations are typically employed for curing this illness, and livestock who are afflicted are frequently treated with medications such amoxicillin and tetracycline. Actions including isolation, sterilization, and proper livestock yield care and removal are additionally beneficial in halting the illness's transmission. Understanding the distribution of anthrax according to areas with outbreaks and associated risks serves to inform healthcare decisions to reduce zoonotic transmission and bioterrorism threats. The animals' efficient control of anthrax safeguards the well-being of people and animals. An extensive branch of mathematical concepts is the study and investigation of various illustrations of actual occurrences. Scientists analyze the actions of particular frameworks employing logical and computational techniques. In order to mimic these natural processes and occurrences, the above method demonstrates novel fractional operations. Many researchers are now employing the fractional operator to analyze the existing system [3–4]. Numerous studies are being conducted using the fractional calculus as a foundation [5-7]. Anthrax is believed to belong to a viral disease caused by the Bacillus Anthracis microorganisms and this illness affects both human and ecosystems, making it a zoonotic illness [8]. The anthrax infectious agent, which attacks animals as opposed to carnivores, is evidently found in soil. Among several animal groups, it is considered the deadliest transferable disease in the world and results in a high and unpredictable mortality rates [9-10] . The group of critters may acquire the Bacillus Anthrax pathogen in a variety of methods, including by ingesting tainted vegetation or water, respiration the germs, or getting into contact with sick animals, according to Gutting et al. [11]. Remember that contaminated animal bodies have a tendency to harm the environment. Each of these settings are the greatest important sources of anthrax microorganisms and can transmit the disease through a single organism to a different one, even if they may persist in grasses for long periods of time in particularly unfavorable conditions. Furthermore, it can take a maximum of eight days for anthrax to grow after a living creature dies, and it requires time for an infected animal to exhibit the clinical symptoms of the disease. The current study presents the numerical solutions of the anthrax disease model used in animals both in integer and fractional form by designing a soft computing platform based on multiple neural network procedures. The integer order form of the anthrax disease model used in animals will be discussed first and then the fractional order derivatives of the anthrax disease model used in animals are solve later to get more precise solutions of the model. The design of the supervised neural network procedures based on the Levenberg–Marquardt backpropagation scheme, Bayesian regularization approach and computational scale conjugate neural network solver is presented through the activation log- sigmoid function or radial basis functions. The process of supervised neural network is used with a single hidden layer structure and deep neural network construction using two or more hidden layers. The numbers of neurons will be selected by performing many tests in the hidden layer(s) for solving the anthrax disease model used in animals. In current decades, the stochastic numerical values have been tested to solve a number of applications. Some of them are Maxwell nanofluid applied on the Buongiorno model [12], novel designed singular fifth order nonlinear system of multi-pantograph differential equations [13] thermal explosion system [14], nonlinear hepatitis B virus model [15], Zika system based reservoirs and human movement [16], multi-fractional order doubly singular model based on lane–emden equation [17], and mosquito spreading system [18]. By keeping in view of these applications, the authors are interested to explore the numerical performances of the mathematical anthrax disease system in animals by using a supervised neural network is used with a single hidden layer structure and deep neural network construction using two or more hidden layers.

A. Sources of Anthrax Infection

Anthrax infection occurs when Bacillus anthracis spores enter the body through different routes. The main sources of infection include [7]:

1) Direct Contact with Infected Animals
   - Livestock such as cattle, sheep, goats, and horses can carry anthrax spores in their blood, tissues, or excretions.
   - Humans handling infected animals or carcasses, such as farmers, veterinarians, and butchers, are at risk of cutaneous anthrax.

2) Contaminated Animal Products
   - Wool, hides, bone meal, and other animal-derived materials from infected animals can carry anthrax spores [8].
   - Workers in industries like tanning, wool processing, and meat handling may get exposed through inhalation or skin contact.

3) Inhalation of Spores (Airborne Transmission)
   - Spores can be released into the air during activities like handling contaminated animal products, disturbing soil with spores, or in bioterrorism attacks.
   - Inhalation anthrax is highly fatal if not treated early.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

4) Consumption of Contaminated Meat
   - Eating undercooked or raw meat from infected animals can cause gastrointestinal anthrax.
   - It leads to severe symptoms such as nausea, vomiting, diarrhea, and even septicemia.
5) Contaminated Soil and Water
   - Anthrax spores can remain in soil for decades and infect animals grazing on contaminated land.
   - Drinking water contaminated with spores can be a source of infection in animals and, in rare cases, humans.
6) Bioterrorism and Laboratory Exposure
   - Bacillus anthracis has been used as a biological weapon due to its ability to form resistant spores.
   - Laboratory workers handling the bacteria are at risk if safety measures are not strictly followed.

B. Anthrax Disease Model

An anthrax disease model is a structured approach used to understand how anthrax spreads, affects populations, and can be controlled. This model helps researchers, epidemiologists, and public health officials analyze disease dynamics, predict outbreaks, and develop effective prevention and response strategies.

Key Components of the Anthrax Disease Model

A basic anthrax model consists of three main components:

1) Host (Humans and Animals): The host refers to individuals or animal populations susceptible to Bacillus anthracis infection. Anthrax primarily affects herbivorous livestock like cattle, sheep, and goats, but humans can also get infected through direct contact with spores. The severity of the disease depends on the route of infection—cutaneous (through skin), inhalation (through breathing in spores), or gastrointestinal (through consuming contaminated meat).
2) Pathogen (Bacillus anthracis Bacteria and Spores): The causative agent, Bacillus anthracis, exists in two forms: an active bacterial state and a dormant spore form. Spores are highly resistant and can survive in soil for decades. When a susceptible host comes into contact with spores, they can germinate into active bacteria, releasing toxins that cause severe illness or death if untreated.
3) Environment (Transmission and Reservoirs): The environment plays a crucial role in the spread and persistence of anthrax. Contaminated soil, water sources, and animal remains serve as natural reservoirs for anthrax spores. Certain environmental factors, such as flooding, drought, and heavy livestock grazing, can disturb the soil and expose buried spores, increasing the risk of outbreaks.

II. LITERATURE REVIEW

Anthrax is a rapidly fatal infectious disease affecting herbivores and people. In the farm animals, cattle and sheep are more susceptible, followed by goats and horses, while dwarf pigs and Algerian sheep are relatively resistant. Bacillus anthracis, the causative agent of anthrax, produces spores and persists for decades in the soil, initiating an outbreak through a favorable climate shift. Anthrax is enzootic in many Asian and African countries, and is reported in Australia, some parts of Europe, and America. The clinical courses of this disease in animals are peracute, acute, subacute, and chronic forms (Md. Emtiaj Alam et al.2022). The widespread application of chaotic dynamical systems in different fields of science and engineering has attracted the attention of many researchers. Hence, understanding and capturing the complexities and the dynamical behavior of these chaotic systems is essential. The newly proposed fractal-fractional derivative and integral operators have been used in literature to predict the chaotic behavior of some of the attractors. It is argued that putting together the concept of fractional and fractal derivatives can help us understand the existing complexities better since fractional derivatives capture a limited number of problems and on the other side fractal derivatives also capture different kinds of complexities (Anastacia Dlamin et al. 2021). introduce and study a tripled system of three associated fractional differential equations. Prior to proceeding to the main results, the proposed system is converted into an equivalent integral form by the help of fractional calculus. Our approach is based on using the addressed tripled system with cyclic permutation boundary conditions. The existence and uniqueness of solutions are investigated. We employ the Banach and Krasnoselskii fixed point theorems to prove our main results (Mohammed M. Matar et al. 2020). One of the most devastating viruses that has significantly impacted human life is the AH1N1/09 influenza virus. Its examination is crucial since the virus is unstable and new varieties with distinct properties are produced every year. To describe these disorders, numerous mathematical models have been presented. In order to investigate this virus, mathematical modeling using fractional differential equations with the Atangana-Baleanu-Caputo derivative and initial values is suggested in this research.

The fuzzy model of the virus is examined due to the confusing and imprecise nature of the virus and the way it affects the human body (Fatemeh Babakordi et al. 2023). a fractional-order model for the anthrax disease between animals based on the Caputo–Fabrizio derivative. First, we derive an existence criterion of solutions for the proposed fractional *CF*-system of the anthrax disease model by utilizing the Picard–Lindelof technique. By obtaining the basic reproduction number $R0$ of the fractional *CF*-system we compute two disease-free and endemic equilibrium points and check the asymptotic stability property. Moreover, by applying an iterative approach based on the Sumudu transform we investigate the stability of the fractional *CF*-system. We obtain approximate series solutions of this system by means of the homotopy analysis transform method, in which we invoke the linear Laplace transform. Finally, after the convergence analysis of the numerical method HATM, we present a numerical simulation of the *CF*-fractional anthrax disease model and review the dynamical behavior of the solutions of this *CF*-system during a time interval (Shahram Rezapour et al. 2020). this work is to provide the numerical solutions of the fluid model by using the stochastic computing paradigms. The linear/exponential stretching sheets on magneto-rotating flow based on the Maxwell nanofluid have been provided using the Buongiorno model with the impacts of uneven heat source/sink, varying thermal conductivity and reactive species. The solutions of this transformed ordinary differential exponential stretching sheet model have been presented using a novel 'radial basis' (RB) activation function together with the Bayesian regularization deep neural network (BRDNN), i.e., RB-BRDNN. The deep neural network is presented into two hidden layers, while thirteen and twenty-five numbers of neurons have been used in the first and second layer. A reference dataset is proposed using the Runge-Kutta scheme for the model. The correctness of the stochastic RB-BRDNN procedure is examined through the comparison of proposed and database results, whereas minimal absolute error values provide the accuracy of the scheme. The reliability and competence of the computing RB-BRDNN solver is authenticated using the state transitions, correlation, regression, and error histograms (Zulqurnain Sabir et al. 2022). The current investigations present the numerical solutions of the novel singular nonlinear fifth-order (SNFO) system of multi-pantograph differential model (SMPDM), i.e., SNFO–SMPDM. The novel SNFO–SMPDM is obtained using the sense of the second kind of typical Emden–Fowler and prediction differential models. The features of shape factor, pantograph along with singular points are provided for all four obtained classes of the SNFO–SMPDM. The extensive use of the singular models is observed in the engineering and mathematical systems, e.g., inverse systems and viscoelasticity or creep systems. For the correctness of the proposed novel SNFO–SMPDM, one case of each class is numerically handled by applying supervised neural networks (SNNs) along with the optimization of Levenberg–Marquardt backpropagation scheme (LMBS), i.e., SNNs–LMBS. A dataset using the traditional variational iteration scheme is designed to compare the proposed results of each case of SNFO–SMPDM. The obtained approximate solutions of each class using the novel SNFO-SMPDM are presented based on the training (80 %), authentication (10 %) and testing (10 %) measures to evaluate the mean square error. Fifteen numbers of neurons, and sigmoid activation function are used in this SNN process. To authenticate the competence, and precision of SNFO–SMPDM, the numerical simulations are accessible by applying the relative measures of regression, error histogram plots, and correlation (Shahid Ahmad Bhat et al. 2024). The motive of this work is to provide the neural investigations using the artificial neural networks (ANNs) through the particle swarm optimization for the singular two-point (STP) boundary value problems (BVPs), i.e., STP-BVPs arising in the theory of thermal explosion. The main purpose of this work is to perform the neural studies based on the large and small (45, 15, 3) neurons together with the complexity cost. The neuron performances have been designated in the form of absolute error. The best results have been achieved in case of large neurons as compared to small neurons, but the complexity cost gets high. The optimization measures of an error function are performed by using the swarming computational global search scheme along with the local search interior-point algorithms (IPA) for the STP-BVPs arising in the theory of thermal explosion. The exactness of the proposed scheme is approved by using the comparison of the obtained and reference solutions. Moreover, the generalization of the data is proposed in terms of statistical analysis to substantiate the capability and trustworthiness of the designed approach for the STP-BVPs (Zulqurnain Sabir et al. 2022). to present a novel fractional Mayer neuro-swarming intelligent solver for the numerical treatment of multi-fractional order doubly singular Lane–Emden (LE) equation using combined investigations of the Mayer wavelet (MW) neural networks (NNs) optimized by the global search effectiveness of particle swarm optimization (PSO) and interior-point (IP) method, i.e. MW-NN-PSOIP. The design of novel fractional Mayer neuro-swarming intelligent solver for multi-fractional order doubly singular LE equation is derived from the standard LE model and the shape factors; fractional order terms along with singular points are examined. The modeling based on the MW-NN strength is implemented to signify the multi-fractional order doubly singular LE model using the ability of mean squared error in terms of the merit function and the networks are optimized with the integrated capability of PSOIP scheme. The perfection, verification and validation of the fractional Mayer neuro-swarming intelligent solver for three different cases of the multi-fractional order doubly singular LE equation are recognized through comparative investigations from the reference results on different measures based on the convergence, robustness, stability and accuracy. Furthermore, the statics interpretations further validate the performance of the proposed fractional Mayer neuro-swarming intelligent solvers (ZULQURNAIN SABIR et al. 2021). The utmost advancements of artificial neural networks (ANNs), software-defined networks (SDNs) and internet of things (IoT) technologies find beneficial in different applications of the smart healthcare sector. Aiming at modern technology's use in the future development of healthcare, this paper presents an advanced heuristic based on Morlet wavelet neural network for solving the mosquito release ecosystem in a heterogeneous atmosphere. The mosquito release ecosystem is dependent of six classes, eggs density, larvae density, pupae density, mosquitoes searching for hosts density, resting mosquito's density and mosquitoes searching for ovipositional site density. An artificial neural network with the layer structure of Morlet wavelet (MWNN) kernel is presented using the global and local search optimization schemes of genetic algorithm (GA) and active-set algorithm (ASA), i.e., MWNN-GA-ASA. The accurateness, reliability and constancy of the proposed MWNN-GA-ASA is established through comparative examinations with Adams method based numerical results to solve the proposed nonlinear system with matching of order 10^{-06} to 10^{-09}. The accuracy and convergence of the proposed MWNN-GA-ASA is certified using the statistical operators based on root mean square error (RMSE), Theil's inequality coefficient (T.I.C) and mean absolute deviation (MAD) operators (ZULQURNAIN SABIR et al. 2017).

III. DISCUSSION AND CONCLUSION

A. *Mathematical Models for Studying Anthrax*

To understand and predict anthrax outbreaks, researchers use mathematical models. These models help simulate the spread of anthrax under different conditions, evaluate control measures, and estimate infection risks [9, 10]. Some common types of models include:

1) SIR Model (Susceptible-Infected-Recovered)
   - This is a basic compartmental model that classifies individuals into three categories:
     - Susceptible (S): Individuals who can contract the disease.
     - Infected (I): Individuals currently carrying and spreading the infection.
     - Recovered (R): Individuals who have survived the infection and developed immunity.
   - The SIR model uses differential equations to predict how an anthrax outbreak might progress over time.

2) SEIR Model (Susceptible-Exposed-Infected-Recovered)
   - This model is an extension of the SIR model and includes an exposed (E) category. Since anthrax has an incubation period before symptoms appear, this model accounts for individuals who have been exposed to the spores but are not yet infectious.

3) Environmental Persistence Models
   - These models consider how anthrax spores survive in the environment, how they resurface after environmental disturbances, and how transmission cycles between animals and humans occur over long periods.

The anthrax disease mathematical model used in animals is one of the nonlinear and complicated differential system, which contains ten different classes and the numerical solutions have been presented by using the proposed stochastic solver. The fractional operator Caputo derivative is used to get more precise solutions of the anthrax disease mathematical model used in animals. An artificial neural network approach using the consistent supervised Bayesian regularization, scale conjugate gradient and Levenburg Backpropogation methods are applied effectively to solve the anthrax disease mathematical model used in animals. An activation sigmoid function along with single layer structure and multiple layers is used in the hidden layers to get the numerical results of the anthrax disease mathematical model used in animals. The reliability of the scheme is observed through the overlapping of the solutions as well as small absolute error values.

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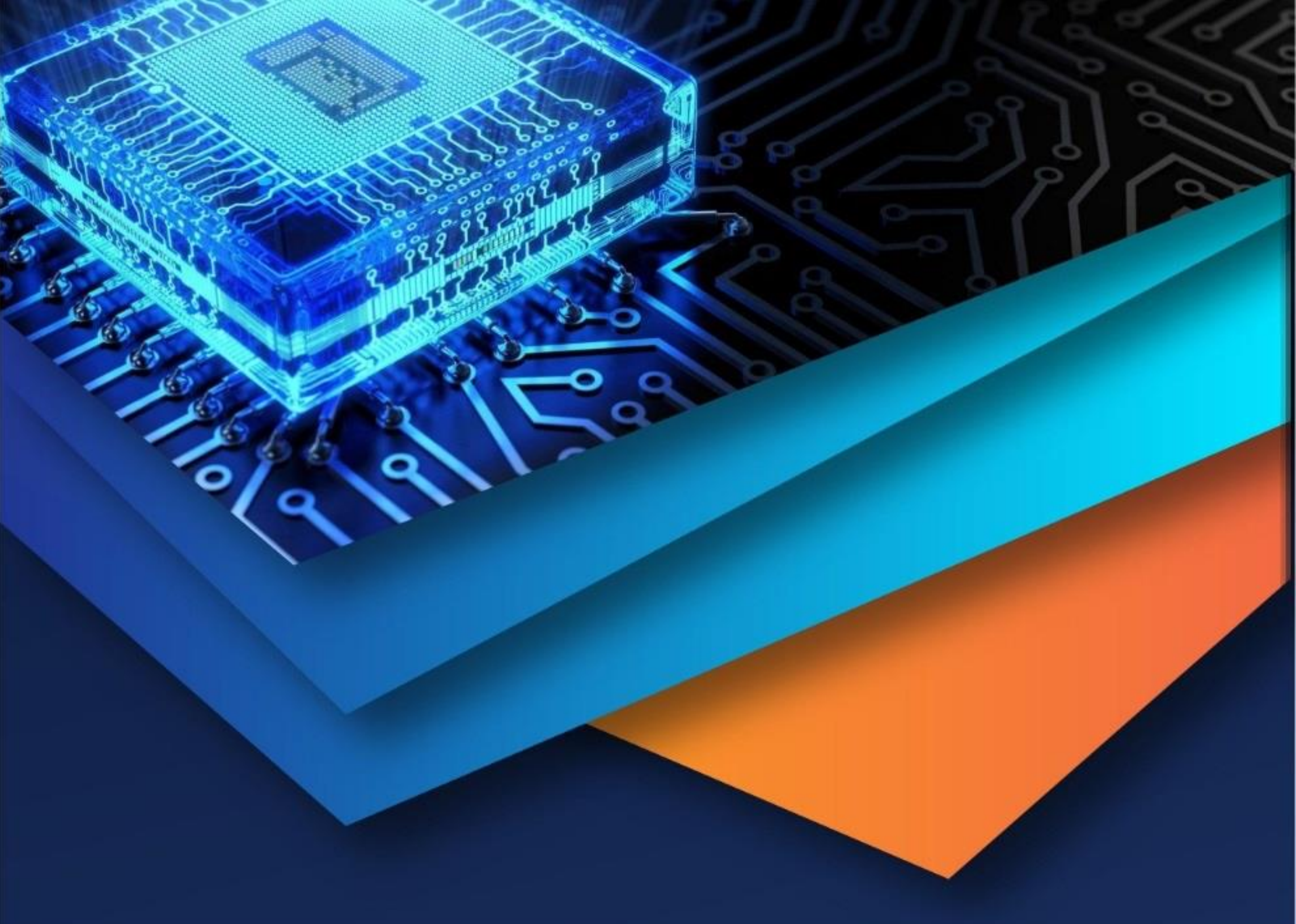

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