A Conceptual Framework Integrating Social Dynamics and Viral Characteristics for Modeling the Risk of Emerging Infectious Diseases

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Abstract

In the face of emerging infectious diseases that have the potential to trigger epidemics and pose threats to public health, understanding the dynamics of infection and the underlying factors is crucial. Our research is focused on developing a simulation tool to evaluate the infection risk associated with emerging infectious diseases. We introduce a conceptual mathematical framework that integrates the complex dynamics of social interactions, as well as the diversity of sociocultural and behavioral practices within a specific social context. Additionally, we take into account the unique characteristics of viruses, such as lifespan and modes of transmission.

Keywords: Multiscale Modeling, Social Dynamics, Infectious Diseases, Infection Risk, Simulation Tool.

A Discrete-time Optimal Control of Multi-Strain Covid-19 Spread

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Abstract
This paper presents a model that explains how mutant strains spread and change within an infectious disease framework, using a discrete-time dynamic system. The study also looks at how controllers can be integrated into the system to control its progression. Solutions are derived, and the relevant objective functional and Hamiltonian are formulated. Pontryagin's Maximum Theorem is used to determine co-state vectors and explain optimal control strategies. The study concludes with a detailed numerical simulation, providing a visual representation and validation of the proposed methodology's effectiveness in managing the infectious disease and its mutant strains in the given context.

Keywords: Mathematical modeling, Optimal control theory, COVID-19, Pontryagin Maximum.

A Mathematical Analysis of a Caputo Fractional-order Cholera Model and its Sensitivity Analysis

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Abstract

This paper presents a formulation of a Caputo fractional-order model to study the dynamics of cholera. Our primary objective is to investigate the behavior of the disease through a comprehensive analysis. Firstly, we establish the existence and uniqueness of the proposed model using the fixed-point theorem. Additionally, we conduct an analysis to ascertain the positivity and boundedness of the model, which confirms its mathematical and epidemiological well posed. Furthermore, we perform a sensitivity analysis to identify key parameters that significantly influence the basic reproduction number. This analysis allows us to determine the important features and their impact on the disease dynamics. Finally, employing effective numerical techniques, we generate various graphical results for the model using appropriate parameter values. By employing the Caputo fractional-order model, conducting rigorous analyses, and employing advanced numerical tools, this paper provides valuable insights into the dynamics of cholera. The findings contribute to our understanding of the disease and aid in the development of effective control and prevention strategies.

Keywords: Cholera; mathematical model; sensitivity analysis; numerical simulations.

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A Mathematical and Sensitivity Analysis of an HIV/AIDS Infection Model

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Abstract
Spanning over a decade, Human Immunodeficiency Virus infection and acquired immunodeficiency syndrome (HIV/AIDS) have become deadly infectious diseases, particularly in developing countries. This challenge has led to the developing of some important HIV/AIDS treatment strategies, such as antiretroviral therapy (ART), among many others. This study presents a mathematical model to investigate the dynamics of HIV/AIDS transmission. Employing mathematical analysis, non-negativity, boundedness, the basic reproduction number $R0$, and the stability of both the disease-free and endemic equilibrium of the proposed model was derived. Normalized forward sensitivity techniques determine the significance and importance of sensitive parameters associated with $R0$. To gain insights into the dynamical behavior of each compartment, an effective numerical scheme was utilized, and the results obtained suggest that there is a need, even if individuals are infected with the virus, to use non-pharmaceutical interventions as control strategies.

Keywords: HIV/AIDS, mathematical model, sensitivity analysis, numerical simulations.

A Mathematical Model For Trichoderma Fungi Kinetics

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Key Words: *Modeling, Ordinary Differential Equations, Partial Differential Equations, Kinetic models, Trichoderma, Enzyme production, Semi-groupe, Global attractor, Semi-implicit Euler schema, finite elements method.*

Abstract: Trichoderma are fungi that grow in almost all soils and have a key role in producing a wide range of diverse and varied enzymes, such as cellulase, which are involved in repressing plant diseases.
In the reference **1** we developed an unstructured mathematical model describing the kinetics of growth and enzyme production of the filamentous fungus Trichoderma in the rhizosphere by integrating the hydrolysis step of organic matter and taking into account the formation of a product (cellulase). This model is a system of four ordinary differential equations (ODE) describing the evolution of the four concentrations, the organic matter, the biomass, the substrate and the product P, which depend on a growth function and the others parameters. Moreover, using the theorem of stable and unstable varieties, and Barbalat's lemma, we have shown (**1**) that the system of ODE evolves towards a global attractor consisting of non-hyperbolic infinite equilibria according to the initial conditions.
By introducing the diffusion of each component, this ODE model can be spatialized to obtain a system of Partial Differential Equations (PDE), of the reaction-diffusion type. We use the theory of the semi-groups of bounded linear operators and its applications to the partial differential equations **2**, **4**, **3** to prove the existence, the uniqueness and the positivity of the solutions of the PDE model. We show, as expected, that the PDE system has an asymptotic behavior similar to that of the ODE system. We then prove the existence of a global attractor based on some results of **3**, **4**. The attractor contains all the equilibrium states of our considered system. This means that from a given initial datum, the trajectory reaches (or converges to) the attractor over time. We carry out the numerical approximation of the model within a variational framework. We propose a full discrete problem based on a semi-implicit Euler schema and the finite elements method. Finally, we present and discuss several numerical simulations in to support the theoretical results.

References

[1] Hardoul, A., Mghazli, Z., *A Complete Mathematical Model For Trichoderma Fungi Kinetics.* submitted and under review (2023).

[2] A. Pazy, *Semigroups of Linear Operators and Applications to Partial Differential Equations.*, Applied Mathematical Sciences, Springer-Verlag, (1983).

[3] Hale, J. K., *Asymptotic Behavior of Dissipative Systems.*, Am. Math. Soc. Providence, RI (1988).

[4] J. K. Hale and S. Verduyn-Lunel, *Introduction to Functional Differential Equations.*, Applied Mathematical Sciences, Springer-Verlag, (1993).

A mathematical model to study resistance and nonresistance strains of influenza: Optimal control approach

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Abstract
Recently, cases of influenza virus resistance are being observed. Resistance is deadly and can cause many pandemics in future. That is why, here we investigate the situation on which the strains exist side – by – side and the difference in their mode of transmission. This paper studies two strain (resistance and non - resistance) flu model. The non-resistant strain mutates to give the resistant strain. These strains are differentiated by their incidence rates which are; bi-linear and saturated for the non-resistant and saturated resistant strain respectively. This will help in studying the difference in the mode of transmission of the two strains. We propose two optimal control strategies consisting on the treatment and media awareness program for the population.

Keywords: Epidemic model, vaccination, stability, optimal control.

A reaction-diffusion model for cancer combined therapy using fractional derivative and delay

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Abstract
In this work, we present a mathematical model based on fractional partial differential equations to treat cancer with two different therapies, oncolytique viruses and MEK inhibitors. Our model take in consideration the dynamics in time and space of uninfected tumor cells, infected tumor cells, free virus particles and the average level of CAR molecules. We show that our presented model is well-posed. Furthermore, we study the equilibrium points as well as the stability of these equilibria. Finally, we give some results to explain the effect of this combined therapy on tumor cells.

Keywords: Fractional derivative, delay, stability, cancer therapy.

A Dynamic SIR Model Considering Human Immunity in Infectious Disease Transmission

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Abstract
In this article, we propose a mathematical model of infectious disease contagion that accounts for population stratification based on immunity criteria. Our goal is to demonstrate the effectiveness of this idea in preventing different epidemics and to lessen the significant financial and human costs these diseases cause. We determined the fundamental reproduction rate, and with the help of this rate, we were able to examine the stability of the free equilibrium point and then propose two control measures. Pontryagin's maximum principle is used to describe the optimal controls, and an iterative approach is used to solve the optimality system. Finally, numerical simulations are carried out in MATLAB to verify the theoretical analysis.

Keywords: Dynamic system, Human immunity, Infectious diseases, Stability, Free equilibrium, Optimal control

An age-structured model for HBV infection with both modes of transmission and capsids

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Abstract
In this work, we propose an age-structured model for hepatitis B virus (HBV) infection with capsids and two modes of transmission that are virus-to-cell and cell-to-cell. The existence of solutions and the dynamical behaviors of the proposed model are rigorously investigated.

Keywords: HBV infection, age-structure, cell-to-cell transmission, uniform persistence, stability.

References

[1] K. Hattaf, Y. Yang, Global dynamics of an age-structured viral infection model with general incidence function and absorption, International Journal of Biomathematics, 11 (5) (2018), 1–18.

[2] K. Hattaf, N. Yousf, A generalized virus dynamics model with cell-to-cell transmission and cure rate, Advances in Difference Equations, (2016), 1–11.

[3] E. M. Warrak, S. Lasfar, K. Hattaf, N. Yousfi, Mathematical analysis of an age-structured viral infection model with latency and general incidence rate, Commun. Math. Biol. Neurosci., (2022), 1–23.

An Integrated Modeling Approach for crowd dynamics in panic situation

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Abstract
Understanding the dynamics of crowds in panic situations is a major challenge for improving public safety during emergency events. At the core of this complexity, emotions and the state of panic play a crucial role in individual and collective decision-making. To explore this essential dimension, our study proposes to adopt an integrated approach, combining an agent-based displacement model with a panic contagion model. This hybrid approach aims to better grasp how panic influences decision-making in a crowd. We examined various scenarios involving homogeneous and heterogeneous crowds, as well as the role of security agents in containing a panic situation.

Keywords: Crowd dynamics, panic contagion, emergency evacuation, decision making

References

Bosse, T., Duell, R., Memon, Z. A., Treur, J., & Van der Wal, C. N. (2015). Agent-based modeling of emotion contagion in groups. *Cognitive Computation*, *7*, 111–136.

Crocq, L. (2016). Secours psychologiques aux victimes d'attentats terroristes: Partie 1: Tableaux cliniques relatifs aux attentats de 1986 et 1995.

Jebrane, A., Argoul, P., Hakim, A., & El Rhabi, M. (2019). Estimating contact forces and pressure in a dense crowd: Microscopic and macroscopic models. *Applied Mathematical Modelling, 74*, 409–421.

ANALYSIS OF A FRACTIONAL SIR MODEL WITH TREATMENT

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Abstract
The aim of this paper is to explore the use of fractional differential equations for describing the dynamics of certain epidemics. The population is divided into susceptible, infected, and recovered (SIR) categories, with different treatment policies in place. We perform a comprehensive analysis, revealing the existence of two equilibrium points in the model (a disease-free equilibrium and an endemic equilibrium). Local asymptotic stability is established for both scenarios, and numerical simulations are provided to illustrate our findings.

Keywords: Epidemiological process, Discrete, time non linear system, positivity, stability, control.

Analysis of typhoid transmission mathematical model with strategies of optimal control

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Abstract
This research examines various control methods to reduce the presence of salmonella bacteria in the environment and limit the spread of typhoid fever worldwide. To achieve this, we use Pontryagin's maximum principle to determine the most effective control measures by solving the optimality system iteratively. We perform numerical simulations using MATLAB to validate our theory.

Keywords: Optimal control, objective function, Pontryagin's maximum principle, typhoid fever

References

[1] H. Abboubakar, L. K. Kombou, A. D. Koko, H. P. E. Fouda and A. Kumar. Projections and fractional dynamics of the typhoid fever: A case study of Mbandjock in the Centre Region of Cameroon. Chaos, Solitons & Fractals, 150, 111129. (2021).

[2] H. Abboubakar and R. Racke. Mathematical modeling, forecasting, and optimal control of typhoid fever transmission dynamics. Chaos, Solitons & Fractals, 149, 111074. (2021).

[3] O. J. Peter, M. O. Ibrahim, H. O. Edogbanya, F. A. Oguntolu, K. Oshinubi, A. A. Ibrahim, ... and J. O. Lawal. Direct and indirect transmission of typhoid fever model with optimal control. Results in Physics, 27, 104463. (2021).

[4] S. S. Musa, S. Zhao, N. Hussaini, S. Usaini and D. He. Dynamics analysis of typhoid fever with public health education programs and final epidemic size relation. Results in Applied Mathematics, 10, 100153. (2021).

Dynamics of a Delayed Fractional-Order Viral Infection Model applied to immunology

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Abstract
In this work, we propose a new fractional-order model to describe the dynamics of a viral infection. This model considers the three modes of transmission, the two modes of infected cells, the humoral immunity exerted by antibodies and the delay in viral production. Furthermore, We prove that our proposed model has three equilibrium points. Finally, we analyze the stability of these equilibrium points and the existence of the Hopf bifurcation.

Keywords: fractional order, hopf bifurcation, stability, immunology, time-delay, viral infection model.

References

[1] C. Rajivganthi, F. A. Rihan, Global dynamics of a delayed fractional-order viral infection model with latently infected cells, Frontiers in Applied Mathematics and Statistics 7 (2021) 1-10.

[2] K. Hattaf, H. Dutta, Modeling the dynamics of viral infections in presence of latently infected cells, Chaos, Solitons and Fractals 136 (2020) 109916.

[3] K. Hattaf, M. I. El Karimi, A. A. Mohsen, Z. Hajhouji, M. El Younoussi, N. Yousfi, Mathematical modeling and analysis of the dynamics of RNA viruses in presence of immunity and treatment : A case study of SARS-CoV-2, Vaccines 11 (2023) 1-17.

Dynamics of a delayed IS-LM model with general investment function and money supply

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Abstract
The purpose of this work is to develop a theoretical analysis of an IS-LM model with the interest rate, general investment, money supply and two fiscal policy delays. The first delay describes the time lag between tax accrual and payment, while the second one refers to the political process that governs public purchasing decisions and actual expenditure. We mainly study the existence of economic equilibrium. Moreover, the local stability of the economic equilibrium and the existence of Hopf bifurcation are investigated.

Keywords: Economics, IS-LM model, Fiscal policy delays, Stability, Hopf bifurcation.

References

[1] M. Elkarmouchi, S. Lasfar, K. Hattaf, N. Yousfi, Spatiotemporal dynamics of a delayed IS-LM model with interest rate and general investment function. Journal of Mathematics and Computer Science 31 (1), 70-80 (2023).

[2] D. Riad, K. Hattaf, N. Yousfi, Mathematical analysis of a delayed IS-LM model with general investment function, The Journal of Analysis 27 (4), 1047-1064 (2019).

[3] K. Hattaf, D. Riad, N. Yousfi, A generalized business cycle model with delays in grossn product and capital stock, Chaos, Solitons and fractals 98, 31-37 (2017).

Dynamics of a new generalized financial model with Hattaf mixed fractional derivative

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Abstract
In this work, we propose a financial model involving the new Hattaf mixed fractional (HMF) derivative. First, we prove that our proposed model is mathematically and financially well-posed. In addition, we investigate the existence of equilibria. Furthermore, the stability analysis of the financial model is rigorously investigated.

Keywords: Hattaf mixed fractional derivative, financial model, stability analysis.

References

[1] K. Hattaf, A new mixed fractional derivative with applications in computational biology, Computation 12 (1) (2024) 1–17.

[2] C. Liping, M.A. Khan, A. Atangana, S. Kumar, A new financial chaotic model in Atangana-Baleanu stochastic fractional differential equations, AEJ-Alex. Eng. J. (2021) 5193–5204.

[3] Y. He, J. Peng, S. Zheng, Fractional-order financial system and fixed-time synchronization, Fractal and Fractional 6(9) (2022) 1–21.

Fractional Optimal Control Model to Study Illicit Drug Usage

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Abstract

One of the serious problems worldwide is the increase in illicit drug usage, which was mainly due to improper maintenance and/or lack of proper principles governing the situation. This paper presents a fractional optimal control problem formulated for the illicit drug usage using a mathematical model with fractional order derivative in Caputo sense. The state and co-state equations were given and the best strategy to significantly reduce the increase in illicit drug usage is found by using two time dependent control measures, (awareness campaign against illicit drug, proper monitoring and guidance, severe punishment to the culprits when caught from government side and from the parents side, taking responsibility of their wards, proper monitoring and all other measures that can be taken to reduce the possibilities of recruiting the new illicit drug users from the susceptible population) and (catching the illicit drug users and punishing them, using rehabilitation centers for monitoring and treatment of light illicit drug users).

Keywords: Optimal control, fractional order model, illicit drug usage, mathematical model.

Global Dynamics of a Generalized Viral Infection Model with Anomalous Diffusion and Distributed Delays

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Abstract
The aim of this work is to propose and investigate the global dynamics of a diffusive viral infection model with distributed delays and cytotoxic T lymphocyte (CTL) immune response. The proposed model takes into account the two modes of transmission virus-to-cell and cell-to-cell, both routes are modeled by two general nonlinear incidence functions. The diffusion into the model is formulated by the regional Laplacian operator. Furthermore, the global asymptotic stability of three equilibria is regourouselly established. Finally, we illustrate our analytical results by numerical simulation.
Keywords: Dynamical biological Systems, general incidence functions, fractional Laplacian operator, asymptotic stability.

References

[1] K. Hattaf, Spatiotemporal dynamics of a generalized viral infection model with distributed delays and CTL immune response, Computation, 7 (2019), 1–16.

[2] A. El Hassani, K. Hattaf, N. Achtaich, Global stability of reaction-diffusion equations with fractional Laplacian operator and applications in biology, Commun. Math. Biol. Neurosci. 2022 (2022) 1–22.

Global dynamics of a model describing viral infection with delayed immune response involving two delays

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Abstract
We study the qualitative behaviour for a model of virus infection with delayed immune response, described by a scalar delay differential equation with two delays. Interested to the study of asymptotic behaviour of the system, we shall investigate asymptotic and global stability results for the given delay differential equation. The scalar functional differential generates a strongly order preserving semiflow with the exponential ordering Then, key theorems are proven using the methods of monotone dynamical systems theory, instead of the classical Lyapunov stability theory. Using monotone dynamical systems theory, we give suffcient conditions of local and global stability of given equilibria dependently to the efficiency of the immune response for virus elimination and the delay of immune response. The obtained results are applied to a class of special forms of the immunity the efficiency function. Moreover, we provide numerical simulations and geometrical description of stability and monotonicity domains.

Keywords: Immune response mathematical modeling, Delay Differential Equations, Monotone dynamical systems, Exponential ordering, Global stability, Asymptotic stability

References

1 N.Bessonov, G.Bocharov, T. M Touaoula, S.Trofimchuk and V.Volpert, Delay reaction-diffusion equation for infection dynamics, Discrete and continuous dynamical systems, series B, 24(5) (2019), pp.2073-2091.

2 G.Bocharov, Modelling the dynamics of LCMV infection in mice: con-

ventional and exhaustive CTL responses. J. Theor. Biol, 192 (1998), pp. 283-308.

3 J.El Karkri and K.Niri, Global asymptotic stability of an SIS epidemic model with variable population size and a delay, Int. J. Dynamical Systems and Differential Equations, 2017, Vol. 7, No. 4, 289-300.

Global stability of fractional reaction-Diffusion systems involving Hattaf fractional time derivative

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Abstract
In this work, we introduce a new approach to constructing Lyapunov functionals for dynamical systems characterized by fractional differential equations and fractional partial differential equations that incorporate Hattaf fractional time derivative. Moreover, the method is applied to establish the global stability of certain fractional virological and economic models.

Keywords: Hattaf fractional derivative, Global stability, reaction-Diffusion.

References

[1] K. Hattaf, A new generalized definition of fractional derivative with non-singular kernel, Computation 8, 2020, 1-9.

[2] K. Hattaf, On some properties of the new generalized fractional derivative with non-singular kernel, Mathematical Problems in Engineering, 2021, 1-6.

[3] K. Hattaf and N. Yousfi, Global stability for fractional diffusion equations in biological systems. Complexity, 2020, 1-6.

HIV-1 dynamics with fractional differential equations under the impact of therapy and CTL immune response

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Abstract

In this study, we propose a mathematical model that incorporates immunological memory, CTL immune response and a general incidence rate to elucidate the dynamics of HIV-1 infection under the impact of Highly Active Antiretroviral Therapy (HAART). Firstly, we show that the developed model is mathematically and biologically well-posed, conducting an examination of the existence of equilibrium points. Moreover, we establish the stability of these equilibrium points. We then analyze the influence of memory and the CTL immune response on the dynamic behavior of the proposed model.

Keywords: HIV, 1 infection, CTL immune response, stability, therapy.

Mathematical analysis of an age-structured SIR epidemic model

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Abstract
L'idée principale de notre travail est de présenter et d'étudier le comportement asymptotique d'un modèle épidémique SIR en tenant compte de la variable d'âge. Tout d'abord, nous avons commencé par présenter notre modèle mathématique structuré par âge sous forme d'un système d'équations aux dérivées partielles. De plus, nous avons prouvé l'existence de la solution de ce modèle. Ensuite, nous avons calculé les points d'équilibre du modèle et développé des résultats théoriques pour leur stabilité locale et globale. Enfin, la méthode des différences finies de caractéristiques est utilisée pour présenter les résultats numériques du modèle épidémique structuré par âge suggéré et les simulations numériques sont réalisées en utilisant MATLAB.

Keywords: SIR epidemic model, Age structured model, Partial differential equations, Stability analysis.

Mathematical model describing the role of adaptive immunity in the evolution of a viral infection

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Abstract
In this paper we introduce a novel mathematical model to characterize the behavior of viral infections when adaptive immunity is present. The proposed model incorporates a non-cytolytic cure, accounting for both cell-to-cell and virus-to-cell transmission modes. It considers the lytic and non-lytic effects of both cellular and humoral immune responses. The model's well-posedness is established. Additionally, five equilibriums are identified, and five threshold parameters governing the model are defined. The global stability of these equilibria are derived from these parameters. Finally, numerical illustrations using specific parameters related to human immunodeficiency virus (HIV) infection are presented to elucidate the model's dynamics.

Keywords: Viral infection, cell, to, cell transmission, virus, to, cell transmission, Cure, adaptive immunity.

MATHEMATICAL MODELING AND MONKEYPOX'S OPTIMAL CONTROL STRATEGY

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Abstract

This study delves into a continuous-time mathematical framework that delineates the transmission dynamics of the monkeypox virus across distinct regions, involving both human and animal hosts. We introduce an optimal approach that encompasses awareness campaigns, security protocols, and health interventions in areas endemic to the virus, aiming to curtail the transmission among individuals and animals, thereby minimizing infections in humans and eradicating the virus in animals. Leveraging the discrete-time Pontryagin principle of maximum, we ascertain optimal controls, employing an iterative methodology to solve the optimal system. Employing Matlab, we conduct numerical simulations and compute a cost-effectiveness ratio. Through a comprehensive cost-effectiveness analysis, we underscore the efficacy of strategies centered around safeguarding vulnerable individuals, preventing contact with infected counterparts—both human and animal—and fostering the utilization of quarantine facilities as the most potent means to govern the spread of the monkeypox virus.

Keywords: Optimal Control, monkeypox virus, spread of monkeypox

[1] Labzai, A., Kouidere, A., Khajji, B., Balatif, O., Rachik, M.Mathematical Modeling and Optimal Control Strategy for a Discrete Time Drug Consump-

tionModel. Discrete Dynamics in Nature and Societythis link is disabled, 2020, 2020, 5671493.

[2] Abderrahim Labzai, Bouchaib Khajji, Omar Balatif, Mostafa Rachik. Discrete mathematical modeling of the propagation of religious ideas: Optimal control approach.

[3] Abderrahim Labzai, Omar Balatif, Mostafa Rachik. Optimal Control Strategy for a Discrete Time Smoking Model with Specific Saturated Incidence Rate.

[4] Omar Balatif, Abderrahim Labzai,Mostafa Rachik. A Discrete Mathematical Modeling and Optimal Control of the Electoral Behavior with regard to a Political Party.

MATHEMATICAL MODELING AND MONKEYPOX'S OPTIMAL CONTROL STRATEGYMATHEMATICAL MODELING AND OPTIMAL CONTROL STRATEGY FOR THE INFLUANZA (H5N1)

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Abstract

This study aims to examine the optimal control strategy for a continuous-time mathematical model of avian influenza. The model comprises eleven compartments, with our focus directed at five categories: potential groups, vulnerable groups, symptomatic virus carriers, asymptomatic virus carriers, virus carriers with severe complications, and virus carriers with complications of lesser severity. Our objective is to identify an effective strategy for diminishing the number of critically ill patients with avian flu and for treating carriers of the avian flu virus. We investigate three control approaches: awareness programs through education and information dissemination, treatment, and psychological support with ongoing monitoring. The Pontryagin's principle of continuous-time maximum is employed to delineate the optimal controls. The study employs MATLAB software for numerical simulations, and the results obtained validate the efficacy of the optimization strategy. Keywords: Avian influenza; Optimal control; Avian disease.

Keywords: Avian influenza; optimal Control ; Avian disease.

References

[1] Labzai, A., Kouidere, A., Khajji, B., Balatif, O., Rachik, M.Mathematical Modeling and Optimal Control Strategy for a Discrete Time Drug Consumption Model.Discrete Dynamics in Nature and Societythis link is disabled, 2020, 2020, 5671493.

[2] Abderrahim Labzai, Bouchaib Khajji, Omar Balatif, Mostafa Rachik. Discrete mathematical modeling of the propagation of religious ideas: Optimal control approach.

[3] Abderrahim Labzai, Omar Balatif, Mostafa Rachik. Optimal Control Strategy for a Discrete Time Smoking Model with Specific Saturated Incidence Rate.

[4] Omar Balatif, Abderrahim Labzai, Mostafa Rachik. A Discrete Mathematical Modeling and Optimal Control of the Electoral Behavior with regard to a Political Party.

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Minimizing Container Oscillations: Innovative Control for Crane Systems

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Abstract
This article discusses the importance of efficient port operations in international trade and the crucial role of cranes in handling heavy containers and bulk goods. One of the biggest problems with crane systems is that containers must be positioned swiftly and accurately at the required place while having their angle of inclination reduced. Minimizing container oscillations is crucial to ensuring that the containers are transported to their intended destination. The paper proposes a control approach that combines first-order sliding mode control (FOCSM) and the extended Kalman filter observer (EKF) to improve the performance of overhead crane systems. The simulation results demonstrate the effectiveness and robustness of the proposed approach in terms of oscillation suppression and positioning accuracy. The research contributes to the advancement of control methodologies in crane systems and has potential applications in various industrial sectors.

Keywords: Double, pendulum effect, Overhead Crane System, Sliding Mode Control, Swing suppression control, Dynamic Model, Extended Kalman Filter

Mixed fractional model for hearing loss due to viral infection

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Abstract:
In this work, we have developed a new fractional mathematical model for hearing loss resulting from infectious diseases using the Hattaf mixed derivative, which includes many forms of fractional derivatives with singular and non-singular kernels. The local and global stability are rigorously established. Furthermore, additional numerical simulations are presented to illustrate our analytical results.

Key Words: *Hearing loss, Viral infection, Hattaf mixed fractional derivative, Stability*

Références

References

[1] Cohen B. E. , Durstenfeld A. and Roehm P. C. (2014), Viral causes of hearing loss: a review for hearing health professionals; Trends in hearing, volume 18, pp. 1-17.

[2] Kouilily, F., Aboulkhouatem, F. E., Yousfi, N., El Khasmi, M., Achtaich, N. (2018). Mathematical model of hearing loss caused by viral infection. Revue Africaine de la Recherche en Informatique et Mathématiques Appliquées.

[3] Hattaf, K. (2023). A New Class of Generalized Fractal and Fractal-Fractional Derivatives with Non-Singular Kernels. Fractal and Fractional, 7(5), 395.

[4] Hattaf, K. (2024). A New Mixed Fractional Derivative with Applications in Computational Biology. Computation, 12(1), 7.

Modeling Emotional Contagion in Pedestrian Flows During Panic Situations

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Abstract

The application of mathematical models to pedestrian flows has greatly enhanced our comprehension of crowd dynamics, with a specific emphasis on understanding the emergence of collective movements resulting from individual interactions. Central to this dynamic is the pivotal role of emotional contagion in influencing decision-making, particularly during panic situations. In this research, we employed a generalized Lotka-Volterra model, meticulously adapted to simulate the intricate dynamics of emotional contagion. Each individual is characterized by their emotional intensity and is presumed to engage in either competition or cooperation with others, depending on their positive or negative perception of the scenario. Pedestrians were categorized into four primary compartments: adapted, panic flight, agitated, and stunned. A comprehensive mathematical analysis of the model was conducted. Simulations carried out across diverse scenarios yielded recommendations and guidelines focused on mitigating the spread of panic within a population. These findings offer valuable insights to inform crowd management strategies and contribute to the reinforcement of safety measures in critical situations.

Keywords: emotional contagion, Lotka, Volterra generalized model, emotional intensity, panic situation.

Modeling the impact of population mobility on the disease spread in urbanized areas

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Abstract

Population mobility was a crucial element in the spread of the many diseases that the world faced in recent years. In this work, we will investigate the impact of mobility within a neighborhood, within the city, and between cities in the same country. We use agentbased models to study how mobility restriction contributes to disease control. We also look at the vaccination as a control tool that relaxes the human mobility restriction. We use different heuristic optimization methods to find the optimal level of mobility restriction and vaccination coverage that keeps the disease non-endemic in the population.

Keywords: infectious diseases, COVID, 19, Agent, based model, optimization.

Modeling plant epidemic propagation

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Abstract
Plants play a vital role in the everyday life of all organisms on Earth. However, at times, plants can become infected with an epidemic. The aim of this study is to develop a deterministic mathematical model of a certain plant epidemic that describes the dynamics of different compartments and investigate the impact of certain control strategies on their spread. We use the tools of optimal control theory, specifically Pontryagin's maximum principle, to characterize these optimal controls.
Finally, some numerical simulations are performed to verify the theoretical analysis using MATLAB.

Keywords: Plant disease epidemiology, Mathematical model, Optimal control.

References

[1] G. Agrios, *"Plant Pathology"*, San Diego, California : Academic Pres (2005).

[2] J. E. Van Der Plank, *"Plant Diseases: Epidemics and Control"*, Edition 3, Academic Press (1963).

[3] N. Bazarra, M. Colturato, J. R. Fernández, M. G. Naso, A. Simonetto and G. Gilioli, *"Analysis of a Mathematical Model Arising in Plant Disease Epidemiology"*, Applied Mathematics and Optimization, Vol. 85, N. 19, pp. 28, (2022).

[4] S. Lenhart and J. T. Workman, *"Optimal Control Applied to Biological Models"*, CRC Press, London, UK (2007).

Multi-Scale Hybrid Modeling of Plant Growth in Response to Environmental Conditions and Soil Nutrient Availability

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Abstract

This paper deals with the development of a multi-scale hybrid model for plant growth in response to environmental conditions and soil nutrient availability. To achieve this, we initiated our investigation by examining the growth patterns of lettuce plants in the context of a field experiment conducted under various environmental conditions, including temperature and radiation, at varying plant densities. Subsequently, we employed different growth models to assess the influence of time, degree days, and effective degree days across different plant densities and during three distinct periods throughout the year.

The proposed model couples the dynamics of length growth based on radiation and temperature with soil nutrient concentration, enabling the simulation of plant weight growth under variable environmental conditions and in interaction with soil nutrients, both without and with branching.

Keywords: multi-scale hybrid model, plant growth, environmental conditions, effective degree days, dynamics of length growth

References

[1] DP Aikman and A Scaife. *Modelling plant growth under varying environment conditions in a uniform canopy*. Annals of botany, 72(5):485–492, 1993.

[2] N Bessonov and V Volpert. *Dynamic models of plant growth : Mathematics and mathematical modelling* Publibook 2006.

Optimal Control of a Frictional Thermo-piezoelectric Contact Problem

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Abstract
In this paper, we provide an optimal control, necessary optimality conditions and a convergence result of regularized problem for a mathematical model which describes frictional contact between a thermo-electro-elastic body and an electrically and thermally conductive foundation. The contact is described by Tresca's friction law including electrical and thermal conductivity conditions. We derive a variational formulation of our model which is given as a coupled system for the displacement, electric potential, and the temperature fields. Then, an existence and uniqueness theorem is established. Our aim here is to present a detailed description to controlling the corresponding deformation and electrical potential in the body, when the foundation temperature is the control. To do this, we introduce an optimal control problem and under some regularity assumptions, we prove the existence of at least one solution. Moreover, we introduce the relate regularized problem and we shows the dependence of this problem with respect to the data and we provide a convergence result. Finally, we provide a necessary optimality condition of the regularized optimal control problem.

Keywords: Thermo, electro, elastic material, Frictional contact, Variational coupled system, Optimality condition and convergence results, Optimal control problem.

Optimal Control of Marine Parasitic Disease: The Case of Anisakiasis

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Abstract
Epidemiological research focusing on aquatic animals is increasingly crucial, evolving into a necessity to safeguard two of the most vital aspects for humans: health and our food sources. Considering that a significant number of human diseases may originate in the aquatic environment, Anisakis, a parasitic nematode with a worldwide distribution, has garnered attention. Various marine cetaceans and pinnipeds serve as definitive hosts, while the larval (L3) developmental stage, infectious to humans, is commonly found in fish and other marine creatures. Human infection occurs inadvertently after consuming raw or undercooked seafood, making Anisakis an emerging public health concern on a global scale. To effectively describe, analyze, and predict the spread of this disease, mathematical models prove to be indispensable. In this work, we formulate and analyze an optimal control problem for epidemiological model designed to capture the dynamics of Anisakis across different hosts and infectious status compartments. Public Health Education and the implementation of aquaculture and fishing methods serve as control variables to minimize the numbers of susceptible humans and infected fish.

Keywords: Aquaculture, Anisakis, parasitic nematode, mathematical models, control variables, Public Health Education.

References

Cantrell, D. L., Groner, M. L., Ben-Horin, T., Grant, J., & Revie, C. W. (2020). Modeling pathogen dispersal in marine fish and shellfish. *Trends in Parasitology, 36*(3), 239–249.

Dobson, A. P., & May, R. (1987). The effects of parasites on fish populations—theoretical aspects. *International Journal for Parasitology, 17*(2), 363–370.

Fleming, W. H., & Rishel, R. W. (2012). *Deterministic and stochastic optimal control* (Vol. 1). Springer Science & Business Media.

Lemos-Paião, A. P., Silva, C. J., Torres, D. F., & Venturino, E. (2020). Optimal control of aquatic diseases: A case study of yemen's cholera outbreak. *Journal of Optimization Theory and Applications, 185*(3), 1008–1030.

Maryam, R., Fouad, L., Imane, E., Yousra, M., & Mostafa, R. (2022). Optimal strategy of vaccination and prevention measures in a seqirs pandemic model. *Commun. Math. Biol. Neurosci., 2022*, Article–ID.

Murray, A. G. (2009). Using simple models to review the application and implications of different approaches used to simulate transmission of pathogens among aquatic animals. *Preventive Veterinary Medicine, 88*(3), 167–177.

Mwasunda, J. A., Irunde, J. I., Stephano, M. A., & Chacha, C. S. (2023). Fish-borne parasitic zoonoses transmission dynamics: The case of anisakiasis. *Informatics in Medicine Unlocked, 38*, 101205.

Nagasawa, K. (1990). The life cycle of anisakis simplex: A review. *Intestinal Anisakiasis in Japan: infected fish, sero-immunological diagnosis, and prevention*, 31–40.

Naylor, R., Fang, S., & Fanzo, J. (2023). A global view of aquaculture policy. *Food Policy, 116*, 102422.

Peeler, E. J., & Taylor, N. G. (2011). The application of epidemiology in aquatic animal health-opportunities and challenges. *Veterinary Research, 42*(1), 94.

Pradeepkiran, J. A. (2019). Aquaculture role in global food security with nutritional value: A review. *Translational Animal Science, 3*(2), 903–910.

Rahmati, A. R., Kiani, B., Afshari, A., Moghaddas, E., Williams, M., & Shamsi, S. (2020). World-wide prevalence of anisakis larvae in fish and its relationship to human allergic anisakiasis: A systematic review. *Parasitology Research, 119*, 3585–3594.

Optimal control problem with free end-time for cancer chemotherapy

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Abstract
The main motivation for this work is to determine the optimal dosage and duration for cancer chemotherapy that minimizes tumor cell number, treatment side effects, and therapy cost using optimal control theory for a model representing the interaction between immune and tumor cells with chemotherapy intervention. The optimal control problem with free end-time has been formulated and the optimal control characterization has been given using the Pontryagin's maximum principle. The optimality system with a second transversality condition for the free end-time is added and solved numerically using a fourth order Runge-Kutta iterative approach and the iterative scheme of the gradient method. The results, with and without chemotherapy, are presented and discussed, and an optimal chemotherapy treatment strategy that has contributed to tumor elimination is suggested, along with the optimal treatment duration.

Keywords: Optimal control, Free end, time problem, Cancer, Chemotherapy.

Optimal control strategies for the spread of scam rumors

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Abstract
Rumors are unverified pieces of information or speculative stories that circulate among people, often through informal channels. These narratives may involve elements of truth, but they are typically exaggerated, distorted, or fabricated, making them unreliable and subject to potential misinformation. Rumors can spread rapidly and influence perceptions, despite lacking credible evidence or official confirmation. In this work, we investigate a deterministic model aimed at elucidating the spread of misleading information 'Scam Rumor' on the internet such as Facebook, Twitter, and similar social media platforms. This model takes into account the behavior of informants in the network. We use optimal control theory to assess the effectiveness of strategies to reduce the spread of scam rumors in social media. Furthermore, we perform numerical simulations to distinguish between the advantages and disadvantages of using the methods we propose, highlighting their potential positive impact on online content accuracy.

Keywords: Optimal control, rumors, compartment models, social network

References

[1] Cheng, Y. and Zhao, L., 2021. Dynamical behaviors and control measures of rumor-spreading model in consideration of the infected media and time delay. Information Sciences, 564, pp.237-253.

[2] Daley, D.J. and Kendall, D.G., 1965. Stochastic rumours. IMA Journal of Applied Mathematics, 1(1), pp.42-55.

[3] Maki, D.P., 1973. Mathematical models and applications: with emphasis on the social, life, and management sciences.

[4] Luo, X., Jiang, H., Chen, S. and Li, J., 2023. Stability and optimal control for delayed rumor-spreading model with nonlinear incidence over heterogeneous networks. Chinese Physics B, 32(5), p.058702.

Population Dynamics under Climate Change: A 2D Modeling Approach with Penalization Method

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Abstract

The current climate change exerts a remarkable influence on population dynamics [1], inducing substantial modifications in habitats and compelling species to adjust their geographic distribution to ensure their persistence. Faced with this reality, populations encounter critical challenges to their survival, being forced to migrate towards more favorable areas, thus exposing themselves to the risk of extinction under the influence of external environmental factors.

One approach to studying the fate of these populations is to use 2D reaction-diffusion models, for instance, by considering a favorable rectangular domain moving at a fixed speed under the influence of climate change. This domain is referred to as the "climate envelope". Generally, this climate envelope undergoes modifications that involve not only simple translations but also shape changes [2], making the theoretical study of these models more complex. Therefore, we propose to use a penalization method [3, 4, 5] to take into account the boundary conditions associated with the initial problem, expecting the problem studied on a fixed fictitious domain to be a good approximation of the initial model.

The objective of this work is the mathematical and numerical analysis of population dynamics in response to climate change, using a penalization method for a moving 2D spatial domain while considering Neumann boundary conditions. We conduct a numerical study of the convergence of the penalized problem with respect to the penalization parameter. Subsequently, we analyze different geometries and reaction terms. Finally, we perform various numerical tests and compare the results with the case of Dirichlet boundary conditions [2], in terms of persistence or extinction of the population.

Keywords: Population dynamics, Climate change, Reaction-diffusion models, Climate Envelope, Penalization method, Neumann boundary conditions

References

[1] G.-R. Walther et al. “Ecological responses to recent climate change”. In: *Nature* 416 (2002), pp. 389–395.

[2] L. Roques et al. “A population facing climate change: joint influences of Allee effects and environmental boundary geometry”. In: *Population Ecology* 50.2 (2008), pp. 215–225.

[3] B. Bensiali, G. Chiavassa, and J. Liandrat. “Penalization of Robin boundary conditions”. In: *Applied Numerical Mathematics* 96 (2015), pp. 134–152.

[4] B. Bensiali and J. Liandrat. “Two-dimensional extension of a penalization method for Neumann or Robin boundary conditions”. In: *ICRAMCS 2022 - International Conference on Research in Applied Mathematics and Computer Science*. Casablanca. Mar. 2022.

[5] B. Bensiali and J. Liandrat. “Two-dimensional extension of a penalization method for Neumann or Robin boundary conditions: a boundary layer approach”. In: *In preparation* (2024).

Spatiotempral dynamics of a delayed prey-predator model with Hattaf-Yousfi functional response and Allee effect

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Abstract

In this work, we investigate a spatiotemporal delayed prey-predator model with Hattaf-Yousfi functional response and Allee effect. We prove that the proposed model is mathematically and ecologically well-posed. Additionally, we study the local stability and the necessary and sufficient conditions for the existence of Hopf bifurcation . Finally, numerical simulations illustrate the effectiveness of the theoretical results.

Keywords: Ecology, prey-predator, reaction-diffusion, Allee effect, stability, Hopf-bifurcation, Hattaf-Yousfi functional response.

References

[1] S. Bouziane, E. Lotfi, K. Hattaf, N. Yousfi, Dynamics of a delayed prey-predator model with Hattaf-Yousfi functional response, Commun. Math. Biol. Neurosci., 2022 (2022), Article ID 104.

[2] S. Bouziane, E. Lotfi, K. Hattaf, N. Yousfi, Stability analysis and Hopf bifurcation of a delayed prey-predator model with Hattaf-Yousfi functional response and Allee effect, Mathematical Modeling and Computing, **2023**, 668-673 (2023).

[3] K. Hattaf, N. Yousfi, A generalized HBV model with diffusion and two delays, Computers, Mathematics with Applications 1. **2015**, 31-40 (2015).

[4] K. Hattaf, Spatiotemporal dynamics of a generalized viral infection model with distributed delays and CTL immune response, Computation. **2019**, 21 (2019)

STABILITY ANALYSIS OF TO A PREDATOR-PREY MODEL WITH TWO EFFORT FUNCTIONS AND HOLLING TYPE IV RESPONSE FUNCTION

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Abstract

In this communication, we introduce a mathematical framework concerning a system involving two prey species and one predator. We examine two distinct fishing areas—one designated as reserved and the other as unreserved. Our model incorporates a type IV Holling response function along with two fishing effort functions that vary with time. Initially, we identify the attraction region where all solutions starting within the positive octant converge. Subsequently, we explore the presence of positive equilibria within the system and analyze their local stability properties.

Keywords: prey-predator, Ordinary differential , equilibria, local stability

References

[1] Verhulst, P.-F.: Notice sur la loi que la population poursuit dans son accroissement. Corresp. Math. Phys. 10, 113–121 (1838).

[2] Volterra, V. (1931). "Variations and fluctuations of the number of individuals in animal species living together". In Chapman, R. N. (ed.). Animal Ecology.

[3] Y. Louartassi, A. Alla, K. Hattaf, A. Nabil, Dynamics of a predator–prey model with harvesting and reserve area for prey in the presence of competition and toxicity, J. Appl. Math. Comput. 59 (2019), 305–321.

[4] Lemnaouar, M. R., M. Khalfaoui, Y. Louartassi, and I. Tolaimate. "Harvesting of a prey-predator model fishery in the presence of competition and toxicity with two effort functions." Commun. Math. Biol. Neurosci. 2019.

[5] B. Dubey, A prey-predator Model with a Reserved Area, Nonlinear Anal., Model. Control. 12 (2007), 479– 494.

Stability analysis of five-dimensional porous model

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Abstract
In this paper, we studied the stability of a five-dimensional model for low Prandtl number in a porous medium. The mathematical model includes the heat equation coupled with the equations of motion under the Boussinesq-Darcy approximation. A system of five ordinary differential equations is obtained using a spectral method. This system is solved numerically by using the fourth-order Runge-Kutta method. We have shown that the first three equilibrium points are stable and the other two equilibria are unstable under certain conditions on the control parameters of the problem. Also, we proved that for a certain value of Rayleigh number and shape parameter, the transition from periodic oscillatory convection to chaotic convection can occur via a period-doubling.
Keywords: Chaos, Stability analysis, Runge–Kutta method

References

Joundy, Y., Rouah, H., Taik, A. (2021). A quasi-periodic gravity modulation to suppress chaos in a Lorenz system. *International Journal of Dynamics and Control*, *9*, 475–493.

Mahmud, M.N., Hashim, I. (2011). Small and moderate Vadasz number chaotic convection in porous media in the presence of non-Boussinesq effects and feedback control. *Physics Letters A*, *375*, 2382–2393.

Saltzman, B. (1962). Finite amplitude free convection as an initial value problem-I. *Journal of the Atmospheric Sciences*, *19*, 329–341.

Vadasz, J.J., Meyer, J.P., Govender, S. (2014). Chaotic and periodic natural convection for moderate and high Prandtl numbers in a porous layer subject to vibrations. *Transport in porous media, 103,* 279–294.

The dynamics of the spread of e-commerce practice behavior: an optimal control approach.

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Abstract
E-commerce is the process of buying and selling goods and services over the Internet. E-commerce customers can make purchases from their computers or mobile phones as well as other touchpoints, including smart watches and digital assistants. E-commerce brings a number of economic benefits to both customers and merchants, but the use of e-commerce remains very limited despite the development of infrastructure, especially the Internet and transportation, because they are considered the backbone of e-commerce. To study the e-commerce model for merchants, we proposed an epidemiological model that fits the studied problem of non-use of e-commerce by some merchants, which wastes some opportunities for the customer in terms of offers or in terms of competitive prices. The merchant also loses the opportunity to open up to new markets without the hassle of traveling. Finally, we used optimal control theory to evaluate the effectiveness of the proposed strategies to encourage merchants to use electronic commerce.

Keywords: Mathematical modeling, E-commerce, Optimal control theory.

References

[1] Burgos, C., Cortés, J. C., Shaikhet, L., Villanueva, R. J. (2018). A nonlinear dynamic age-structured model of e-commerce in spain: Stability analysis of the equilibrium by delay and stochastic perturbations. Communications in Nonlinear Science and Numerical Simulation, 64, 149-158.

[2] Kendall, D.G., 1956, January. Deterministic and stochastic epidemics in closed populations. In Proceedings of the third Berkeley symposium on mathematical statistics and probability (Vol. 4, pp. 149-165). Berkeley: University of California Press.

[3] W. H. Fleming and R. W. Rishel, Deterministic and Stochastic Optimal Control, Springer, New York, NY, USA, 1975.

Unveiling Tumor Growth Dynamics through Mathematical Modeling with the Logistic Model

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Abstract

The logistic model is a mathematical equation, describes tumor growth's sigmoidal curve. It enables researchers to: Analyze growth patterns and predict tumor size, estimate the maximum achievable tumor volume (carrying capacity), compare treatment efficacy by incorporating treatment parameters. However, the model: Ignores spatial variations within tumors, neglects the tumor-immune system interaction. Future advancements aim to develop more models that are sophisticated that: Deepen understanding of tumor biology, optimize treatment strategies through personalized predictions, and facilitate development of novel cancer therapies. While acknowledging limitations, the logistic model remains a foundation for mathematical modeling in tumor growth research, paving the way for advancements in cancer treatment.

Keywords: mathematical model,tumor growth,logistic model,tumor prediction,compartment model

References

[1] Ribba, B. et al, *"Un modèle d'inhibition de la croissance tumorale pour les gliomes de bas grade traités par chimiothérapie ou radiothérapie"*, Clin. Cancer Rés. 18 , 5071-5080 (2012).

[2] Mahlbacher GE, Reihmer KC, Frieboes HB, *"Mathematical modeling of tumor-immune cell interactions"*,J Theor Biol. 2019 May 21.

[3] Atuegwu, *"NC et al Intégration de données IRM pondérées en diffusion et d'un modèle mathématique simple pour prédire la CELLULARITÉ des tumeurs du sein pendant la chimiothérapie néoadjuvante"*, Magné. Réson. Méd. 66 , 1689-1696 (2011).

[4] N. Bazarra, M. Colturato, J. R. Fernández, M. G. Naso, A. Simonetto and G. Gilioli, *"Analysis of a Mathematical Model Arising in Plant Disease Epidemiology"*, Applied Mathematics and Optimization, Vol. 85, N. 19, pp. 28, (2022).

[5] Al-Tameemi M, Chaplain M, d'Onofrio A. *"Evasion of tumours from the control of the immune system: consequences of brief encounters"*, Biology direct 7, 31 (2012).