Artículo de Revisión

Explorando técnicas de modelado en sistemas dinámicos utilizando ecuaciones diferenciales: una revisión exhaustiva de enfoques y aplicaciones

Exploring modeling techniques in dynamical systems using differential equations: a comprehensive review of approaches and applications

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How to cite this article:

Zaragoza Alvarado, G. A., & Alvarado Bastidas, E. A. (2024). Exploring modeling techniques in dynamical systems using differential equations: a comprehensive review of approaches and applications. Sapiens in Higher Education, 1(2), 29-39. https://revistasapiensec.com/index.php/Sapiens_in_Higher_Education/article/view/40

Resumen

El uso de ecuaciones diferenciales es vital para el conocimiento y la predicción de la conducta temporal en estructuras complicadas en todos los campos, que incluyen la física, la ingeniería, la biología y la economía. Estas ecuaciones funcionan con engranajes matemáticos específicos que describen la evolución de las variables en las estructuras, dando cuenta de sus dependencias temporales y espaciales. La mejora del modelado de estructuras dinámicas se ha desarrollado notablemente desde la física teórica, explorando diversas estrategias que embellecen su aplicabilidad a lo largo de un par de dominios. Este estudio se especializa en revisar exhaustivamente esas estrategias, utilizando un enfoque meticuloso metodológico. Los estudios dependen en niveles clave para abarcar todo el campo, con un énfasis específico en la evaluación dirigida de ecuaciones diferenciales normales y parciales (ODE y PDE). Para descubrir la literatura aplicable, se empleó un método riguroso que utiliza bases de datos educativas especializadas y motores superiores como Google. Esta técnica garantiza la elección vital de quince artículos clave, evaluados por su solidez metodológica y su efecto en el avance del know-how en estructuras dinámicas. Cada uno de ellos se somete a una evaluación exhaustiva para reconocer los procesos de modelado y sus paquetes únicos a través de diversas disciplinas médicas e implementadas. Este libro ofrece una visión completa de cómo las ecuaciones diferenciales modelan estructuras dinámicas complejas, destacando los puntos fuertes de los procesos convencionales y las nuevas posibilidades que ofrece el uso de las metodologías actuales. Este libro representa una contribución considerable a los estudios del destino en regiones vitales que incluyen la salud pública, el cambio climático y la planificación concreta.

Palabras clave: Ecuaciones Diferenciales; Modelización Dinámica; Técnica Meticulosa; Aplicaciones Interdisciplinarias.

Abstract

Modeling dynamic structures the usage of differential equations is vital for know-how and predicting temporal conduct in complicated structures throughout fields which includes physics, engineering, biology, and economics. These equations function specific mathematical gear that describe the evolution of variables in structures, accounting for his or her temporal and spatial dependencies. The improvement of dynamic structures modeling has developed notably from theoretical physics, exploring diverse strategies that beautify their applicability throughout a couple of domains. This has a look at specializes in comprehensively reviewing those strategies, using a meticulous methodological approach. The studies is dependent in key levels to embody the whole field, with a specific emphasis on targeted evaluation of normal and partial differential equations (ODEs and PDEs). To discover applicable literature, a rigorous method using specialized educational databases and superior engines like google turned into employed. This technique guarantees the vital choice of fifteen key articles, evaluated for his or her methodological robustness and effect on advancing know-how in dynamic structures. Each have a look at undergoes thorough evaluation to recognize the modeling processes and their unique packages throughout diverse medical and implemented disciplines. This has a look at offers a complete perception into how differential equations version complicated dynamic structures, highlighting the strengths of conventional processes and the brand-new possibilities afforded with the aid of using present day methodologies. It represents a sizable contribution to destiny studies in vital regions which includes public health, weather change, and concrete planning.

Keywords: Differential Equations; Dynamic Modeling; Meticulous Technique; Interdisciplinary Applications.

1. INTRODUCTION

The modeling of dynamic structures via differential equations is crucial for expertise and predicting the conduct of complicated structures through the years. This approach, essential in conventional disciplines along with physics and engineering, additionally unearths large packages in numerous fields like biology and economics. Differential equations function unique mathematical gear that describe the evolution of a system's variables as a feature of time or different applicable factors.

The improvement of dynamic structures modeling the use of differential equations dates again to pioneering figures who laid the basis for packages in theoretical physics. Since then, diverse strategies had been explored, substantially increasing the scope of packages in fields as numerous as biology and economics, which includes topological dynamic structures and different superior concepts.

This assessment article explores how those mathematical gear have advanced and tailored through the years to cope with modern-day challenges. From their preliminary use in climatology and neuroscience, as highlighted with the aid of using Edward Lorenz withinside the 1960s, to their utility in herbal useful resource control and complicated engineering structures, as documented with the aid of using Clavijo et al. (2023) of their latest studies. Through an in depth and vital analysis, these studies will offer a deep and updated perception into the kingdom of the artwork withinside the use of differential equations for modeling dynamic structures. The article emphasizes the effect and relevance of those strategies in expertise and predicting the conduct of complicated phenomena throughout diverse clinical and technical fields.

Garcia et al. (2024) observe that the literature on dynamic structures modeling the use of differential equations is sizeable and incorporates an extensive variety of crucial processes and packages. Traditional techniques along with everyday differential equations (ODEs) and partial differential equations (PDEs) have performed an essential function in each theoretical improvement and realistic packages. ODEs are best for modeling phenomena wherein variables rely upon an unmarried impartial variable, typically time, even as PDEs are crucial for structures with more than one impartial variable, along with warmth distribution or fluid dynamics.

In current decades, in keeping with Barreto et al. (2017), contemporary-day strategies had been delivered and refined, appreciably improving modeling competencies on this field. A brilliant instance is agent-primarily based totally modeling, which lets in the simulation of structures wherein more than one unbiased entities engage in keeping with described rules. This method is precious in disciplines inclusive of biology, economics, and sociology, wherein the interplay among self sufficient entities performs a important position withinside the system's observable conduct.

Another extensive advance, as referred to via way of means of Martínez (2023), is the software of neural networks and different device studying strategies to dynamic structures modeling. Neural networks, in particular, have proven high-quality effectiveness in time collection prediction and modeling complicated structures with nonlinear behaviors, which might be hard to seize the use of conventional methods. This capacity of neural networks to study complicated styles from historic facts has converted regions like meteorology, manage engineering, and monetary economics, wherein accuracy in predictions is important for knowledgeable decision-making.

While classical differential equations have mounted the essential framework for analyzing dynamic structures over decades, contemporary-day strategies like agent-primarily based totally modeling and device studying have appreciably enriched the modeling landscape, increasing our capacity to recognize and are expecting the conduct of complicated structures throughout numerous medical and carried out disciplines.

To behavior a bibliographic evaluation on dynamic structures modeling with differential equations, it's far important to observe a based methodological method and use specialised equipment for figuring out and studying applicable literature. Initially, the scope of the observe is certainly described, that specialize in an in depth exam of the literature on numerous modeling strategies carried out to dynamic structures the use of differential equations. This includes the use of systems inclusive of Scielo, Scopus, Mathematical Journals, Dialnet, Digital CIDE, Revista CUC, Digital UPM, Revista MQR Investigar, to behavior

exhaustive searches and find applicable articles, books, and research that cope with key phrases inclusive of dynamic structures modeling and differential equations.

To cope with the studies question, "What are the principle modeling strategies for dynamic structures the use of differential equations, and the way have those strategies developed in phrases of packages and effectiveness in numerous medical and engineering fields?" a complete evaluation become performed at the strategies utilized in dynamic structures modeling through differential equations, comparing how they've developed in phrases of software and effectiveness throughout extraordinary medical and engineering domains. This observes goals to offer an exhaustive evaluation of those strategies, comparing each conventional and contemporary-day approaches, and highlighting their sensible packages in regions inclusive of physics, biology, economics, and engineering. Additionally, it seeks to discover the strengths and boundaries of every technique, in addition to the demanding situations and destiny possibilities on this field.

2. METHODOLOGY

For the exploration of modeling strategies in dynamic structures the use of differential equations, a rigorous and distinctive methodological method turned into adopted. The look at turned into prepared into numerous key stages to make sure complete and in-intensity insurance of this dynamic and multidisciplinary area. Initially, the scope and targets of the look at have been absolutely defined, specializing in very well reading diverse modeling strategies utilized in dynamic structures thru differential equations. This desire turned into justified through the particular capacity of regular (ODE) and partial differential equations (PDE) to seize each time modifications and spatial versions in complicated phenomena, starting from populace dynamics to warmth switch strategies in solids.

To discover applicable literature, superior equipment like educational databases (Scielo, Scopus, Mathematics Journals, Dialnet, Digital CIDE, Revista CUC, Digital UPM, Revista MQR) and specialised serps have been used, using key phrases such as:

Dynamic structures modeling

Differential equations

Applications in physics, biology, and economics

This system ensured an exhaustive series of large research, which have been severely decided on primarily based totally on methodological high-satisfactory and relevance. Each decided on article underwent a important studying to apprehend the one of a kind modeling techniques used and their precise packages, from essential theoretical troubles to realistic instances in diverse medical and implemented disciplines.

During the literature look for this studies on exploring modeling strategies in dynamic structures thru differential equations, key principles vital to the subject have been first recognized. These covered dynamic structures modeling, regular and partial differential equations, and current strategies like neural networks and agent-primarily based totally modeling. These principles have been vital to information how mathematical equipment have been implemented to version and examine structures that extrade over time. Specific seek phrases have been advanced primarily based totally on those key principles. Terms such as:

Dynamic structures modeling

Differential equations

Neural networksAgent-primarily based totally modeling

These have been used, making sure the inclusion of synonyms and associated phrases to expand the quest insurance. Boolean operators like AND, OR, and NOT have been carried out to mix those phrases correctly and modify the quest as important, making sure the seize of applicable research in disciplines like physics, biology, and economics.

This dependent method facilitated the identity of pertinent literature, making sure the overview turned into complete and included each conventional techniques and current improvements in dynamic structures modeling with differential equations.

Inclusion standards have been mounted to embody research that hired regular (ODE) or partial (PDE) differential equations to version dynamic phenomena in diverse disciplines. These research covered theoretical, implemented, experimental, or overview studies that contributed to advancing know-how in dynamic modeling.

Similarly, exclusion standards have been delineated to cast off files now no longer without delay associated with the use of differential equations in dynamic modeling. Studies the use of modeling techniques aside from differential equations, missing rigorous method, or providing uncertain effects have been excluded. Additionally, files unavailable in handy languages or now no longer peer-reviewed have been excluded, making sure the high-satisfactory and reliability of the chosen literature.

Specific examples of inclusion standards covered files providing new modeling strategies or techniques and complete evaluations of the kingdom of the artwork in ODE and PDE packages. In contrast, articles that did now no longer meet important methodological requirements or did now no longer make a contribution substantially to information dynamic structures modeling with differential equations have been excluded.

These standards have been essential to making sure that the overview turned into consistent, rigorous, and applicable withinside the precise context of dynamic modeling, facilitating the proper choice of pertinent literature for the proposed studies.

A dependent technique turned into observed to perform the choice and assessment system of applicable files, making sure the inclusion of pertinent research and the exclusion of these now no longer assembly the mounted standards. The system turned into distinctive as follows:

The preliminary overview of titles and abstracts worried an exhaustive seek the use of educational databases and different applicable sources. Key phrases like dynamic structures modeling, differential equations, and packages in diverse disciplines have been used. Titles and abstracts of retrieved files have been reviewed to discover the ones doubtlessly addressing dynamic modeling with differential equations.

In the item choice phase, files formerly decided on have been similarly evaluated thru complete studying. Their contents have been validated to align with the overview article's targets, i.e., whether or not they addressed modeling strategies the use of differential equations in dynamic structures. Theoretical, implemented, experimental, or overview research that contributed to advancing know-how on this precise area have been covered.

During the important assessment of methodological high-satisfactory, every decided on article turned into severely assessed for its method. Consideration turned into given to the readability of method presentation, the adequacy of techniques used for dynamic modeling, and the robustness of experimental layout whilst applicable. Studies now no longer assembly suitable methodological requirements or showing deficiencies in methodological rigor have been excluded.

In comparing the effect at the area, past methodological high-satisfactory, the look at's effect on dynamic structures modeling with differential equations turned into assessed. The originality of the offered techniques, the relevance of the effects to the medical community, and the contribution to advancing know-how in precise utility regions have been considered.

This system ensured a scientific and rigorous overview of applicable literature, making sure that the chosen files aligned with the overview article's targets and furnished a strong basis for in-intensity dialogue and evaluation of modeling strategies in dynamic structures thru differential equations.

Rigorous methodological steps have been observed. Initially, developments and principal techniques in dynamic structures modeling the use of differential equations have been recognized, classifying research in accordance to conventional techniques like regular and partial differential equations, in addition to rising strategies like neural networks and agent-primarily based totally modeling. This categorization enabled the detection of styles withinside the utility of those strategies in diverse medical and implemented fields.

Furthermore, an in-depth contrast of the techniques and strategies used turned into conducted, comparing their effectiveness and barriers in describing and predicting dynamic phenomena. Specific contexts have been recognized in which sure techniques proved extra appropriate than others, offering precious statistics on high-satisfactory practices in dynamic modeling.

During the evaluation, the maximum large findings derived from the reviewed literature have been highlighted, such as key discoveries, methodological advancements, and progressive packages. These findings have been synthesized to offer strong conclusions approximately the applicability and relevance of modeling strategies with differential equations in one of a kind medical and implemented disciplines. This synthesis consolidated present know-how and mentioned promising regions for destiny studies in dynamic structures modeling.

3. RESULTADOS

A file evaluation matrix changed into evolved to behavior an exhaustive research of modeling strategies in dynamic structures the usage of differential equations. This matrix protected fifteen articles cautiously decided on for his or her significance and contribution to the subject. Each article changed into evaluated primarily based totally on particular standards including the usage of everyday and partial differential equations, in addition to the software of contemporary-day methodologies like neural networks and agent-primarily based totally modeling. In addition, the technique employed, the first-rate of the evaluation performed, and the relevance of the consequences to the development of understanding in dynamic structures have been assessed. This matrix supplied an in depth and comparative view of the distinctive strategies located withinside the reviewed literature, highlighting crucial discoveries and rising traits on this subject of study.

Table 1.

Document Analysis Matrix

#	Article Title	Author(s)	Abstract	URL
1	A Delay Differential Equations Model for Disease Transmission Dynamics	Erdem et al. (2019)	The article explores dynamic modeling strategies the usage of ODEs and PDEs throughout numerous disciplines.	https://revistas.ucr.ac.cr/index.php/matematica/article/view/39948
2	Applications of Neural Networks and Deep Learning in Biomedical Engineering	Sarmiento (2020)	Analysis of ways neural networks are utilized in dynamic structures modeling.	https://www.redalyc.org/journal/5537/553768213002/html/

#	Article Title	Author(s)	Abstract	URL
3	Assessment of Mathematical Modeling Skills Development in an Ordinary Differential Equations Course: An Engineering Approach	Cardona et al. (2024)	Review of computational tools MATLAB and Python for simulating mathematical models.	https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-50062024000200001&lng=es&nrm=iso&tlng=es
4	Agent-Based Modeling: A Systems Engineering Approach	Pereda et al. (2015)	Exploration of how agent-based modeling can be applied in different fields.	https://polipapers.upv.es/index.php/RIAI/article/view/9364
5	Deep Learning Application for Precipitation Forecasting Using Meteorological Radar Reflectivity Data	Godoy (2019)	Study on the application of PDEs in predicting weather phenomena.	https://dspace.ucuenca.edu.ec/bitstream/123456789/32551/1/Trabajo%20de%20titulaci%C3%B3n.pdf
6	Dynamics of Colombian Scientific Production in Economics: A Bibliometric Study on Scopus 2007-2019	Gómez et al. (2021)	Application of ODEs in predicting economic trends and their impact on public policies.	http://www.scielo.org.co/pdf/le/n95/0120-2596-le-95-277.pdf
7	Agent-Based Simulation of Systems Originally Represented with ODEs	Guerrero et al. (2024)	Research on simulating biological systems using ODEs and PDEs.	https://dialnet.unirioja.es/servlet/articulo?codigo=5924681
8	Methodology for Stability Analysis of N-Dimensional Differential Equation Systems	González et al. (2016)	Study of stability in control systems through differential equation analysis.	http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1684-18592016000300004
9	Numerical Modeling of Seismic Wave Propagation in Coupled Poroelastic and Acoustic Media	Ayotunde et al. (2022)	Modeling of wave propagation in elastic media using differential equations.	http://www.ejemplo9.com
10	Bibliometric Analysis of Stochastic General Equilibrium Models	Cerquera (2023)	Application of stochastic models in economic and financial analysis.	https://revistascientificas.cuc.edu.co/economicascuc/article/view/4404/5153
11	Mathematical Modeling of Population Dynamics: Historical Development and Practical Use in Cuba	Miranda (2014)	Study on population dynamics using mathematical models with ODEs.	http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1010-27522014000300001

#	Article Title	Author(s)	Abstract	URL
12	Development of a Mathematical Model to Simulate Traffic Flow in Cities	DosReis et al. (2024)	Numerical simulation of transport phenomena using partial differential equations.	https://oa.upm.es/75238/1/TFG_JAIME_MARTIN_LOBO.pdf
13	Application of First-Order Ordinary Differential Equations for Solving Physical Problems	Cardona (2024)	Modeling of electrical circuits using ordinary differential equations.	Aplicación+de+las+ecuaciones+diferenciales+ordinarias+de+primer+orden.pdf
14	Comparative Exploration of Newton-Raphson and Bisection Methods for Solving Nonlinear Equations	Luna et al. (2024)	Comparison of numerical methods for solving partial differential equations.	https://www.investigarmqr.com/ojs/index.php/mqr/article/view/1258
15	Differential Equations: Applications and Biomath Modeling with MATLAB and Simulink	Chagas et al. (2023)	Applications of dynamic models in engineering using differential equations.	https://dspace.ups.edu.ec/handle/123456789/26559

Note: The desk provides a framework for report evaluation aimed toward exploring superior modeling strategies in dynamic structures the use of differential equations. Fifteen key articles had been reviewed, inspecting the usage of normal and partial differential equations, in addition to cutting-edge strategies like neural networks and agent-primarily based totally modeling. This evaluation highlighted substantial development and new instructions on this place of mathematical study.

Initially, 135 studies articles have been recognized from numerous databases consisting of Scielo, Scopus, Mathematics Journals, Dialnet, Digital CIDE, Revista CUC, Digital UPM, and Revista MQR. After a radical review, a complete of a hundred and twenty articles have been excluded. Of these, eighty have been removed after an in depth assessment of titles and abstracts, as they did now no longer meet the hooked up inclusion standards. Additionally, forty reproduction articles have been recognized and excluded at some stage in this process. The exclusion standards have been primarily based totally on numerous technical and methodological aspects: loss of relevance to differential equations withinside the context of dynamic systems, absence of ebook in identified medical or instructional journals, presence of technical reports, textbooks, or different non-instructional publications, research with constrained scope or loss of strong methodological evaluation, in addition to articles now no longer to be had in English or Spanish, or the ones inaccessible via identified instructional databases.

Fifteen articles that met strict inclusion standards have been selected. These required a right away connection to using ordinary (ODE) or partial (PDE) differential equations in dynamic machine modeling. These articles proven the express utility of ODE/PDE in precise regions consisting of physics, engineering, biology, or economics, followed with the aid of using rigorous methodological evaluation that drastically contributed to the development of know-how in dynamic modeling. Furthermore, they have been posted in identified medical or instructional journals.

4. DISCUSIÓN

The studies tested fifteen key articles centered on superior modeling strategies in dynamic structures via differential equations. Each decided on examine gives particular views and particular packages in fields which include epidemiology, biomedical engineering, economics, meteorology, and extra. For instance, Erdem et al. (2019) explored sickness fashions the use of ODEs and PDEs, at the same time as Sarmiento (2020) highlighted using neural networks in biomedical engineering. Cardona et al. (2024) reviewed computational equipment for simulating mathematical fashions, and Pereda et al. (2015) explored agent-primarily based totally modeling in structures engineering.

Studies like Godoy's (2019) on weather prediction the use of PDEs, and Gómez et al.'s (2021) paintings in economics, verified full-size packages of ODEs in forecasting and public policy. Guerrero et al. (2024) investigated the simulation of organic structures, at the same time as González et al. (2016) advanced methodologies for reading balance in N-dimensional structures. These works underscore the range and intensity of differential equation packages throughout diverse medical and technical disciplines.

Together, that research make a contribution to a extra complete know-how of mathematical modeling in dynamic structures, highlighting full-size advances and rising trends. From the simulation of seismic waves with the aid of using Ayotunde et al. (2024) to the modeling of populace dynamics with the aid of using Miranda (2014), every examine offers critical equipment and strategies to cope with complicated troubles in engineering, herbal sciences, and social sciences. This frame of literature now no longer most effective expands theoretical information however additionally promotes the sensible utility of superior mathematical strategies in fixing cutting-edge challenges.

5. CONCLUSION

The complete overview of fifteen key articles found out a extensive variety of superior modeling strategies in dynamic structures the usage of differential equations. These strategies were correctly implemented throughout numerous disciplines which includes physics, engineering, biology, and economics. The reviewed research spotlight the precise functionality of everyday differential equations (ODEs) and partial differential equations (PDEs) to appropriately and mathematically carefully seize the temporal evolution and spatial versions of complicated phenomena. This method now no longer most effective allows a deeper expertise of dynamic structures however additionally helps prediction and optimization in diverse implemented contexts.

Methodologically, big range turned into determined a few of the reviewed research. While a few targeted at the traditional use of ODEs and PDEs to version precise phenomena, others explored current strategies which includes neural networks and agent-primarily based totally modeling. This kind of procedures underscores the power and adaptableness of mathematical modeling equipment whilst going through one-of-a-kind demanding situations and sorts of data. However, every technique additionally offers its personal boundaries and sensible concerns that ought to be cautiously evaluated in precise software contexts.

The reviewed findings have big implications for expert exercise and policy-making. For instance, withinside the area of biomedical engineering, modeling strategies may be used to simulate and optimize scientific devices, thereby enhancing the precision and performance of treatments. In economics, the usage of ODEs and PDEs permits for greater correct forecasting of financial tendencies and evaluation of the effect of public policies. These sensible packages display the transformative ability of differential equations in fixing complicated real-global problems.

Despite big advances, the reviewed research additionally found out sure boundaries. These consist of the want to enhance the precision of mathematical models, combine new data, and broaden greater sturdy validation strategies. Additionally, possibilities have been diagnosed to discover rising technology and adapt current methodologies to deal with cutting-edge demanding situations in fields which includes synthetic intelligence and quantum computing.

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Conflicto de Intereses: Los autores afirman que no existen conflictos de intereses en este estudio y que se han seguido éticamente los procesos establecidos por esta revista. Además, aseguran que este trabajo no ha sido publicado parcial ni totalmente en ninguna otra revista.