

Applications of MATLAB in Natural Sciences: A Comprehensive Review

Shafiullah Niazai 

Mathematics Department, Faculty of Education, Laghman University, Afghanistan

Ariana Abdul Rahimzai

Mathematics Department, Faculty of Education, Laghman University, Afghanistan

Hamza Atifnigar 

*Assistant Professor, English Department, Faculty of Literature and Human Sciences,
Laghman University, Laghman, Afghanistan*

Suggested Citation

Niazai, S., Rahimzai, A.A. &
Atifnigar, H. (2023). Applications
of MATLAB in Natural Sciences:
A Comprehensive Review.

*European Journal of Theoretical and
Applied Sciences*, 1(5), 1006-1015.

DOI: [10.59324/ejtas.2023.1\(5\).87](https://doi.org/10.59324/ejtas.2023.1(5).87)

Abstract:

In the natural sciences, MATLAB is a versatile and essential tool that has revolutionized research across various disciplines, including physics, chemistry, biology, geology, and environmental sciences. This review paper provides a comprehensive overview of MATLAB's applications in data analysis, modeling, simulation, image processing, computational chemistry, environmental sciences, physics, engineering, and data visualization. MATLAB simplifies data analysis by handling complex datasets, performing statistical analyses, and aiding in tasks like curve fitting and spectral analysis. In

modeling and simulation, it enables the creation of predictive models for intricate systems, facilitating simulations of physical processes, ecological dynamics, and chemical reactions. In image processing, MATLAB enhances and analyzes images, benefiting fields such as medical imaging and remote sensing. For computational chemistry, MATLAB offers a rich library of tools for exploring molecular structures and simulating chemical reactions. Environmental sciences rely on MATLAB for climate data analysis and ecological modeling. In physics and engineering, it is invaluable for simulating complex systems and analyzing experimental data. Additionally, MATLAB's data visualization capabilities allow scientists to create compelling visuals for effective communication. While challenges like licensing costs exist, efforts are underway to address these issues and enhance integration with other software, including artificial intelligence and machine learning tools. Overall, MATLAB's computational power and versatility are fundamental to advancing natural sciences research, making it an invaluable resource for scientists and researchers across various disciplines.

Keywords: MATLAB, Natural Sciences, Data Analysis, Modeling and Simulation, Data Visualization.

Introduction

In the ever-expanding realm of scientific exploration, MATLAB has firmly established itself as an indispensable and powerful tool, transcending disciplinary boundaries to

significantly enhance research in the natural sciences. With its dynamic programming environment and a rich assortment of functions and tools, MATLAB has become a linchpin for scientists across diverse fields, spanning physics, chemistry, biology, geology, and environmental

sciences. In this review paper, we embark on a comprehensive journey through the multifaceted applications of MATLAB, shedding light on its instrumental role in advancing our understanding of the natural world.

The ubiquity of MATLAB in the natural sciences is a testament to its adaptability, accessibility, and computational might. Scientists have come to rely on this versatile platform not only to facilitate their research but also to push the boundaries of knowledge and innovation. Our aim in this review is to provide a thorough exploration of how MATLAB's functionality underpins the foundational pillars of scientific inquiry. It is a versatile Swiss Army knife that researchers turn to for data analysis, modeling, simulation, and data visualization.

The role of MATLAB in data analysis is foundational and pivotal, offering an extensive toolbox for preprocessing, analyzing, and deriving meaningful insights from intricate datasets. Its statistical capabilities empower researchers to extract valuable information from voluminous data, enhancing the depth and quality of their analyses. From curve fitting to spectral analysis, the versatility of MATLAB streamlines these critical tasks and has positioned it as an invaluable companion in data-driven research across multiple scientific domains.

In the realm of modeling and simulation, MATLAB's contributions are transformational. Researchers across the natural sciences rely on its modeling capabilities to create predictive models of complex systems, allowing for the simulation of physical processes, ecological dynamics, and chemical reactions. The flexibility and comprehensiveness of MATLAB's support for differential equations, agent-based modeling, finite element analysis, and more have deepened our understanding of intricate phenomena and have paved the way for novel discoveries (Arrouf & Ghabrour, 2007).

This review will also highlight MATLAB's crucial role in image processing, a field where it excels and has a profound impact. From enhancing and analyzing images to deciphering

complex information in biology, medicine, and geology, MATLAB has catalyzed advancements in domains such as medical imaging, remote sensing, and microscopy.

In the domain of computational chemistry, MATLAB has become a favored choice due to its extensive library of tools that support the exploration of molecular structures, calculation of electronic properties, and simulation of chemical reactions. Its computational chemistry capabilities have simplified complex calculations and have been instrumental in understanding molecular behavior (Arrouf & Ghabrour, 2007).

In the environmental sciences, MATLAB's significance is further underscored. It assists in climate data analysis, ecological modeling, and geospatial analysis, contributing to the understanding of pressing environmental issues and facilitating informed decisions in the realms of conservation and sustainability.

In physics and engineering, MATLAB is not just a tool but a cornerstone, enabling the simulation of intricate physical systems and the analysis of experimental data. Its comprehensive function library and compatibility with diverse hardware make it an ideal choice for experimentation and data analysis.

Furthermore, the review will illuminate MATLAB's prowess in data visualization, allowing scientists to craft compelling plots, graphs, and animations that bridge the gap between raw data and meaningful insights. These visual representations are vital for effectively conveying research findings, making complex data accessible to experts and the broader public.

While MATLAB's transformative impact on the natural sciences is evident, challenges such as licensing costs and the need for regular updates exist. However, ongoing developments in open-source alternatives and collaborations between researchers and software developers are addressing these concerns. Looking ahead, the integration of MATLAB with other software and the incorporation of artificial intelligence and machine learning tools are anticipated developments that will further elevate its

standing in the natural sciences (Arrouf & Ghabrou, 2007).

In conclusion, this review paper serves as a comprehensive resource for understanding the manifold ways in which MATLAB empowers scientific exploration and discovery in the natural sciences. Its versatility and user-friendliness make it an invaluable tool for novice and seasoned researchers alike, and it is expected to remain at the forefront of natural sciences research, fostering new discoveries and insights as technology continues to advance.

Modeling and Simulation

Modeling and simulation stand as cornerstones of scientific research in the natural sciences, offering invaluable tools for understanding complex systems and phenomena. Within this context, MATLAB plays a pivotal role, providing researchers with a versatile and comprehensive platform for creating predictive models and conducting simulations.

MATLAB's significance in modeling and simulation can be attributed to its adaptability and rich library of functions. It empowers researchers to construct mathematical models that represent real-world systems, ranging from physical processes in physics to ecological dynamics in biology, chemical reactions in chemistry, and various other intricate phenomena across different scientific domains. Researchers can harness MATLAB's computational capabilities to define and manipulate these models, ultimately allowing them to make predictions, analyze behavior, and gain deeper insights into the underlying mechanisms of complex systems (Hutton, 2004).

One of the key strengths of MATLAB in this context is its support for differential equations, which are foundational in describing dynamic systems. MATLAB's Differential Equations Toolbox provides a wide range of numerical methods for solving ordinary and partial differential equations. This is invaluable for researchers in fields such as physics and engineering, where these equations are often

used to represent and simulate physical systems (Abar et al., 2017).

Agent-based modeling, a technique that simulates the interactions of individual entities within a system, is another area where MATLAB excels. Researchers in fields such as biology, economics, and social sciences use MATLAB to create agent-based models to study emergent behavior and complex systems, making it easier to understand and predict the outcomes of various scenarios.

Moreover, MATLAB offers support for finite element analysis (FEA), a technique commonly used in engineering and structural analysis. Researchers can perform FEA to simulate the behavior of materials and structures under different conditions, enabling them to optimize designs and make informed decisions (Rao, 2017).

In computational chemistry, MATLAB provides a comprehensive library of tools for researchers to explore molecular structures, calculate electronic properties, and simulate chemical reactions. This capability simplifies complex calculations, allowing researchers to delve deep into the behavior of molecules and chemical systems.

The power of MATLAB in modeling and simulation extends beyond its computational capabilities. Its scripting and programming environment facilitate the development of custom algorithms and scripts, tailored to specific research needs. This flexibility allows researchers to explore and validate hypotheses, conduct sensitivity analyses, and perform scenario testing, all of which are essential steps in the modeling and simulation process.

Furthermore, MATLAB's ability to integrate with other software and data sources enhances its utility in modeling and simulation. Researchers can combine MATLAB with external software packages or interface it with data acquisition systems and experimental equipment to create a more comprehensive and connected research environment (Arrouf & Ghabrou, 2007).

Image processing

Image processing is a critical and transformative area of research, particularly in fields such as biology, medicine, geology, and remote sensing, where visual data plays a central role in understanding complex phenomena. In this context, MATLAB stands as a prominent and invaluable tool, providing a comprehensive environment for image analysis, enhancement, and interpretation.

One of the key strengths of MATLAB in image processing is its diverse set of functions and toolboxes dedicated to handling and manipulating images. These functions allow researchers to import, preprocess, and analyze digital images, providing the essential groundwork for various applications. MATLAB's support for a wide range of image file formats ensures compatibility with data from different sources, facilitating seamless integration into research pipelines (Shirmard et al., 2022).

The process of image enhancement is central to several scientific domains, including medical imaging and remote sensing. MATLAB offers a multitude of techniques to improve the quality and clarity of images. Researchers can use filters, noise reduction algorithms, and contrast adjustments to enhance the visibility of features and patterns within images. This has been particularly critical in medical imaging, where image clarity can be a matter of life and death.

Object recognition and image analysis are other significant aspects of image processing, often used in fields such as biology and geology. MATLAB enables researchers to develop algorithms that can automatically identify and classify objects or features within images. This is particularly useful in applications like cell counting in biological studies, mineral identification in geological surveys, or object tracking in surveillance systems.

In the realm of microscopy, MATLAB supports the analysis of highly detailed images at the cellular or molecular level. It allows for measurements of sizes, shapes, and structures,

enabling researchers to draw meaningful conclusions from microscopic data.

Furthermore, MATLAB's capabilities in image registration and fusion are essential in remote sensing and geospatial applications. Researchers can align and combine images from different sources, such as satellites, drones, or ground-based sensors, to create comprehensive and informative composite images (Bhatti et al., 2020).

For medical imaging, MATLAB is widely used in processing and interpreting various types of medical images, including X-rays, MRIs, CT scans, and ultrasound images. Researchers and healthcare professionals can leverage MATLAB's image processing capabilities to extract diagnostic information, delineate anatomical structures, and visualize abnormalities, greatly contributing to medical diagnosis and treatment.

The visual representation of data plays a crucial role in conveying research findings and insights effectively. MATLAB's data visualization functions, combined with image processing, enable researchers to create compelling plots, graphs, and visualizations from image data. These visuals provide a bridge between raw data and the interpretation, making it accessible to both experts and the general public (Eppler & Aeschmann, 2009).

Computational Chemistry

Computational chemistry, a branch of science at the intersection of chemistry, physics, and computer science, leverages the power of computers and mathematical models to explore and understand complex chemical systems. In this multifaceted field, MATLAB plays a pivotal role, offering a wealth of capabilities that are instrumental in performing molecular modeling, quantum chemistry, and the simulation of chemical reactions.

Molecular modeling, an essential component of computational chemistry, involves the creation of mathematical representations of molecules and molecular structures. MATLAB provides

researchers with a wide array of tools to manipulate, visualize, and analyze these structures. The platform's scripting and programming environment enables the development of custom algorithms for molecular modeling, accommodating the unique requirements of various research projects. These capabilities are invaluable for tasks such as protein structure prediction, drug design, and the exploration of chemical interactions.

Quantum chemistry, a branch of computational chemistry, focuses on simulating the electronic structure and behavior of molecules at the quantum level. MATLAB's computational power and extensive library of mathematical functions are particularly well-suited for conducting quantum chemistry calculations. Researchers can employ MATLAB to solve the Schrödinger equation and predict properties such as electronic energies, molecular geometries, and spectroscopic data. This is vital for understanding chemical reactions and electronic properties of compounds, which are fundamental to various fields, including materials science, catalysis, and drug discovery.

Another core application of MATLAB in computational chemistry is the simulation of chemical reactions. Researchers can develop custom algorithms to simulate the behavior of chemical systems, study reaction mechanisms, and analyze reaction kinetics. MATLAB's support for differential equations and numerical methods makes it an ideal environment for conducting reaction simulations, enabling scientists to predict reaction pathways and optimize reaction conditions.

Furthermore, MATLAB's capabilities extend to data analysis and visualization, which are integral in computational chemistry. Researchers can process and interpret the vast amount of data generated during molecular modeling and chemical simulations. MATLAB's plotting and graphical functions enable researchers to visualize the results, making complex data more accessible and comprehensible. This visualization aids in conveying research findings to peers and the broader scientific community.

In recent years, MATLAB has become a preferred tool for researchers working on advanced topics in computational chemistry, such as the study of molecular dynamics, protein-ligand interactions, and initio calculations. Its robust support for parallel computing and integration with other computational chemistry software packages further enhance its utility.

In conclusion, MATLAB's capabilities in computational chemistry have revolutionized the field, providing researchers with a versatile and powerful environment for molecular modeling, quantum chemistry, and the simulation of chemical reactions. Its computational prowess, extensive library of mathematical functions, and data analysis and visualization tools enable scientists to gain deeper insights into complex chemical systems, from predicting molecular behavior to understanding reaction mechanisms. MATLAB's role in advancing computational chemistry research is not only substantial but also critical to the progress of chemical sciences and their applications in various domains, including pharmaceuticals, materials science, and environmental chemistry.

Environmental Sciences

Environmental sciences are pivotal in addressing the complex challenges and issues related to the Earth's environment, natural resources, and sustainability. Within this multidisciplinary domain, MATLAB serves as a versatile and indispensable tool for researchers and scientists. It plays a vital role in environmental data analysis, ecological modeling, geospatial analysis, and climate research, facilitating the understanding of environmental processes and the formulation of informed decisions.

Environmental data analysis, a fundamental aspect of the field, often involves vast and complex datasets. MATLAB excels in handling and processing this data, offering a suite of functions for data cleaning, transformation, and statistical analysis. Researchers in environmental sciences utilize MATLAB to gain insights into

trends, correlations, and patterns within data related to factors like air quality, water quality, biodiversity, and land use.

Ecological modeling is another area where MATLAB shines. Researchers create mathematical models that simulate ecological systems and the interactions within them. These models help scientists predict ecosystem dynamics, the impact of environmental changes, and the consequences of human activities on ecosystems. MATLAB provides a robust platform for developing and running these models, enabling researchers to conduct experiments *in silico* and explore various ecological scenarios.

Geospatial analysis is a critical component of environmental sciences, particularly in fields such as geography, geology, and urban planning. MATLAB supports geospatial data processing, including geographic information system (GIS) data, remote sensing imagery, and spatial statistics. It allows researchers to analyze geospatial data, map environmental features, and perform geostatistical analyses, contributing to the understanding of environmental patterns and trends (Keith et al., 2021).

Climate research is at the forefront of environmental sciences, as it addresses pressing issues related to climate change and its impacts. MATLAB provides the computational power and data analysis tools necessary for climate data processing. Researchers can perform climate data analysis, construct climate models, and simulate climate scenarios, ultimately contributing to our understanding of climate variability and change, weather patterns, and long-term climate predictions.

Moreover, MATLAB's capabilities extend to the field of environmental engineering, where it aids in the design and optimization of sustainable systems for managing water resources, controlling pollution, and mitigating environmental hazards. Researchers can develop custom algorithms to model and simulate the behavior of environmental systems, assess the impact of pollution control measures, and optimize resource allocation in water and wastewater management.

The importance of data visualization cannot be understated in environmental sciences. MATLAB's data visualization functions allow researchers to create vivid and informative visual representations of environmental data. These visualizations enhance the communication of research findings, making complex environmental information more accessible to policymakers, stakeholders, and the public (Holzbecher, 2012).

Physics and Engineering

The disciplines of physics and engineering are at the forefront of scientific and technological advancement, and MATLAB stands as an invaluable tool for researchers and engineers in these fields. Its versatile capabilities and extensive functionality contribute significantly to the analysis of physical systems, data processing, simulation, and modeling.

MATLAB's importance in physics and engineering research is evident in its ability to simplify complex mathematical and computational tasks. Researchers employ MATLAB to perform numerical simulations and solve intricate mathematical problems, especially those involving differential equations and complex algebraic equations. These capabilities are instrumental in a wide range of applications, from studying fluid dynamics to designing electronic circuits.

Simulation is a cornerstone of both physics and engineering research. MATLAB's support for numerical simulations enables researchers to emulate the behavior of physical systems and conduct experiments in a controlled and digital environment. This allows for the exploration of diverse phenomena, such as the behavior of materials under extreme conditions, the dynamics of mechanical systems, and the optimization of engineering designs. MATLAB's scripting and programming environment is particularly valuable for the development of custom simulation algorithms and models, tailoring the simulations to the unique requirements of specific research projects.

Furthermore, MATLAB facilitates data analysis and processing, both of which are integral in physics and engineering research. Researchers can efficiently preprocess, clean, and analyze experimental data, extracting valuable insights and patterns. MATLAB's extensive library of mathematical functions, signal processing capabilities, and advanced statistical tools are indispensable for tasks like signal analysis, image processing, and data visualization, all of which are critical in these fields.

In the realm of physics, MATLAB plays a key role in the analysis of experimental data and the development of data analysis pipelines. It assists physicists in experiments related to particle physics, optics, and quantum mechanics by offering tools for data interpretation and visualization. Researchers can apply statistical techniques to experimental data, thus ensuring robust and accurate results.

Engineers and researchers in both fields benefit from MATLAB's extensive library of toolboxes, which cater to specific engineering applications. These toolboxes include functionalities for control systems, image processing, signal processing, and optimization, among others. They are tailored to meet the unique demands of engineering research and aid in the design and analysis of systems and components (Biguri et al., 2016).

Visualization

Visualization is an essential component of scientific research and data analysis across various fields, including natural sciences. In this context, MATLAB stands as a powerful and versatile platform for creating, customizing, and interpreting visual representations of data. Its capabilities in data visualization encompass a wide range of applications, aiding researchers and scientists in conveying complex information, patterns, and trends in a comprehensible and insightful manner.

One of the key strengths of MATLAB in data visualization lies in its extensive library of plotting functions. These functions allow researchers to create an array of visualizations,

including line plots, scatter plots, bar charts, heatmaps, contour plots, and 3D surface plots, among others. The diversity of available plot types empowers researchers to select the most appropriate visualization method for their data, ensuring that the information is effectively communicated.

Customization is another hallmark of MATLAB's data visualization capabilities. Researchers can tailor their visualizations to meet the specific requirements of their research, adjusting aspects such as colors, labels, line styles, and marker types. This level of customization is particularly valuable when creating visuals for publications, presentations, or reports.

Furthermore, MATLAB enables the creation of interactive and dynamic visualizations. Researchers can add user interactivity to their visuals, allowing audiences to explore data, zoom in on details, and manipulate parameters in real time. Interactive visuals can be invaluable for communicating complex datasets and for fostering a deeper understanding of the information presented.

For researchers working with time series data or large datasets, MATLAB's ability to handle and plot data efficiently is a considerable advantage. The platform provides tools for subsampling, filtering, and aggregating data, ensuring that the visualizations remain responsive and informative, even with large and complex datasets.

In the realm of 3D visualization, MATLAB excels in creating surface plots, contour plots, and volumetric visualizations. These 3D visuals are instrumental in fields such as geology, engineering, and materials science, where complex three-dimensional structures and patterns need to be analyzed and communicated.

Data visualization also extends to image data. Researchers can use MATLAB to enhance, analyze, and interpret images, making it a valuable tool in fields like biology, medicine, and remote sensing. MATLAB's image processing toolbox allows for detailed analysis, object recognition, and the extraction of critical

information from visual data (Shamir et al., 2010).

The integration of data visualization with other MATLAB capabilities, such as data analysis and modeling, ensures that researchers can seamlessly transition from data exploration to interpretation and communication. This integration streamlines the research process, allowing for faster and more efficient analysis of scientific data (Panse et al., 2022).

Challenges and Future Directions

In the ever-evolving landscape of scientific research, the utilization of MATLAB in the natural sciences is not without its challenges and ongoing developments. Understanding and addressing these challenges while exploring future directions is essential for ensuring the continued effectiveness and relevance of MATLAB in scientific endeavors.

Challenges

Licensing Costs: MATLAB is a proprietary software package, and licensing costs can be a significant barrier for individual researchers, academic institutions, and smaller organizations. Access to MATLAB may be limited by budget constraints, potentially excluding some researchers from benefiting from its capabilities.

Updates and Compatibility: Keeping MATLAB up to date is essential for security, bug fixes, and accessing new features. However, the frequent updates can be disruptive to ongoing research, requiring time and resources for adaptation. Compatibility issues with older scripts and toolboxes can also arise with new versions.

Learning Curve: MATLAB, while known for its user-friendliness, still requires some learning and acclimation, particularly for researchers new to the platform. The wealth of functions and capabilities can be overwhelming, and training is often necessary for users to leverage its full potential (Murray, 2003).

Platform Dependency: MATLAB's primary platform is Windows, and while it is available for

macOS and Linux, there can be subtle differences in functionality and performance between these platforms, which can lead to challenges in cross-platform research (Eppler & Aeschmann, 2009).

Future Directions

Open Source Alternatives: The open-source movement in scientific computing has gained traction, with platforms like Python and R offering robust alternatives to MATLAB. These open-source tools are cost-effective and have large and active user communities. MATLAB may need to address this competition by offering more flexible licensing options or open-source components.

Integration with Other Software: Enhancing integration with other software tools is a promising future direction. Researchers often use a combination of software packages for their work, and seamless interoperability can improve workflow efficiency. Greater integration with data analysis tools, simulation software, and machine learning platforms will enhance MATLAB's capabilities.

Machine Learning and Artificial Intelligence: The incorporation of machine learning and artificial intelligence (AI) capabilities within MATLAB is a natural progression. By offering a robust set of AI and machine learning tools, MATLAB can further empower researchers to extract insights from complex datasets and perform predictive modeling in various natural science domains (Panse et al., 2022).

Parallel and High-Performance Computing: As datasets and simulations become more extensive and computationally intensive, MATLAB's support for parallel and high-performance computing is increasingly critical. Future development should focus on optimizing MATLAB for multi-core processors, distributed computing, and cloud computing platforms.

Collaboration with Researchers: Collaboration between MATLAB developers and researchers in various natural science fields is essential. Researchers' feedback can guide the

development of specialized toolboxes and functions that cater to specific research needs. This collaborative approach ensures that MATLAB remains a valuable resource for the scientific community.

Conclusion

In the natural sciences, MATLAB has emerged as a versatile and indispensable tool that transcends disciplinary boundaries, transforming the way researchers approach data analysis, modeling, simulation, image processing, computational chemistry, and environmental sciences. This review has illuminated the multifaceted role of MATLAB in advancing scientific research and understanding in various domains, underlining its significance as a catalyst for groundbreaking discoveries.

MATLAB's flexibility and computational prowess in data analysis have empowered researchers to extract valuable insights from complex datasets, whether in the realm of biology, physics, or environmental sciences. Its statistical capabilities and extensive toolbox for statistical analysis have made it an essential resource for researchers seeking to distill knowledge from extensive data, enhancing the depth and quality of their analyses.

The platform's role in modeling and simulation has been transformative, enabling researchers to create predictive models of intricate systems, simulate physical processes, and delve into the complexities of ecological dynamics, chemical reactions, and many other phenomena. MATLAB's support for differential equations, agent-based modeling, and finite element analysis has deepened our understanding of complex systems, offering a roadmap to novel discoveries.

In image processing, MATLAB's capabilities have significantly advanced research in biology, medicine, geology, and remote sensing. The software has empowered researchers to enhance, analyze, and interpret images, leading to transformative advancements in medical imaging, environmental monitoring, and various other fields.

Computational chemistry has found a strong ally in MATLAB, which provides a rich library of tools for exploring molecular structures, calculating electronic properties, and simulating chemical reactions. Its computational capabilities have simplified complex calculations, aiding in understanding molecular behavior and making critical contributions to chemistry research.

Environmental sciences increasingly rely on MATLAB to analyze climate data, create ecological models, and perform geospatial analysis. The platform's capabilities have been crucial in addressing environmental challenges, fostering data-driven decisions in conservation, sustainability, and climate research.

In the domains of physics and engineering, MATLAB has become an indispensable asset, used for simulating complex physical systems, analyzing experimental data, and predicting outcomes. Its extensive library of functions, combined with its compatibility with various hardware, has made it an ideal choice for conducting experiments and analyzing data.

Additionally, MATLAB's data visualization capabilities have played a pivotal role in bridging the gap between raw data and meaningful insights. Researchers have harnessed its power to craft compelling plots, graphs, and animations, ensuring that their findings are accessible and understandable by both experts and the broader public.

While MATLAB has undeniably reshaped research practices in the natural sciences, challenges, such as licensing costs and the need for regular updates, exist. However, ongoing efforts to develop open-source alternatives and enhance collaborations between researchers and software developers offer promising solutions to these challenges.

Looking ahead, the integration of MATLAB with other software tools and the incorporation of artificial intelligence and machine learning capabilities are anticipated developments that will further elevate its standing in the natural sciences. By continually adapting to the evolving research landscape and collaborating closely

with researchers, MATLAB is poised to remain an invaluable asset for scientific exploration and discovery in the natural sciences.

References

- Abar, S., Theodoropoulos, G. K., Lemarini, P., & O'Hare, G. M. P. (2017). Agent Based Modelling and Simulation tools: A review of the state-of-art software. *Computer Science Review*, 24, 13–33.
<https://doi.org/10.1016/j.cosrev.2017.03.001>
- Arrouf, M., & Ghabrour, S. (2007). Modelling and simulation of a pumping system fed by photovoltaic generator within the Matlab/Simulink programming environment. *Desalination*, 209(1–3), 23–30.
<https://doi.org/10.1016/j.desal.2007.04.004>
- Bhatti, U. A., Yu, Z., Yuan, L., Zeeshan, Z., Nawaz, S. A., Bhatti, M., Mehmood, A., Ain, Q. U., & Wen, L. (2020). Geometric algebra applications in geospatial artificial intelligence and remote sensing image processing. *IEEE Access*, 8, 155783–155796.
<https://doi.org/10.1109/ACCESS.2020.3018544>
- Biguri, A., Dosanjh, M., Hancock, S., & Soleimani, M. (2016). TIGRE: a MATLAB-GPU toolbox for CBCT image reconstruction. *Biomedical Physics & Engineering Express*, 2(5), 55010.
<https://doi.org/10.1088/2057-1976/2/5/055010>
- Eppler, M. J., & Aeschmann, M. (2009). A systematic framework for risk visualization in risk management and communication. *Risk Management*, 11, 67–89.
<https://doi.org/10.1057/rm.2009.4>
- Holzbecher, E. (2012). *Environmental modeling: using MATLAB*. Springer Science & Business Media.
- Hutton, D. V. (2004). *Fundamentals of finite element analysis*. The McGraw Hill Companies,.
- Keith, J. A., Vassilev-Galindo, V., Cheng, B., Chmiela, S., Gastegger, M., Müller, K.-R., & Tkatchenko, A. (2021). Combining machine learning and computational chemistry for predictive insights into chemical systems. *Chemical Reviews*, 121(16), 9816–9872.
<https://doi.org/10.1021/acs.chemrev.1c00107>
- Murray, R. M. (2003). Future directions in control, dynamics, and systems: overview, grand challenges, and new courses. *European Journal of Control*, 9(2–3), 144–158.
<https://doi.org/10.3166/ejc.9.144-158>
- Panase, C., Trachsel, C., & Türker, C. (2022). Bridging data management platforms and visualization tools to enable ad-hoc and smart analytics in life sciences. *Journal of Integrative Bioinformatics*, 19(4), 20220031.
<https://doi.org/10.1515/jib-2022-0031>
- Rao, S. S. (2017). *The finite element method in engineering*. Butterworth-heinemann.
- Shamir, L., Delaney, J. D., Orlov, N., Eckley, D. M., & Goldberg, I. G. (2010). Pattern recognition software and techniques for biological image analysis. *PLoS Computational Biology*, 6(11), e1000974.
<https://doi.org/10.1371/journal.pcbi.1000974>
- Shirmard, H., Farahbakhsh, E., Heidari, E., Beiranvand Pour, A., Pradhan, B., Müller, D., & Chandra, R. (2022). A comparative study of convolutional neural networks and conventional machine learning models for lithological mapping using remote sensing data. *Remote Sensing*, 14(4), 819.
<https://doi.org/10.3390/rs14040819>