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Editorial

Nonlinear System Modelling and Control: Trends, Challenges, and Future Perspectives

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1. Introduction

Nonlinear systems engineering has undergone a profound transformation with the rapid development of computational tools and advanced analytical methods. In the past, engineers often relied on simplified linear approximations or hand-derived models, but modern computational techniques have become indispensable for modelling, analysing, and controlling complex nonlinear dynamics [1,2]. As digital computation matured, nonlinear system theory evolved from a mathematically challenging niche to a central pillar of modern engineering practice. Numerical solvers, symbolic tools, and high-performance computing environments have enabled rigorous treatment of behaviours such as multistability, bifurcations, saturation effects, time delays, and hybrid dynamics—phenomena that linear models cannot adequately capture [3]. This shift has transformed how researchers design controllers, predict system responses, and ensure stability in increasingly complex applications ranging from robotics and energy systems to transportation and cyber–physical infrastructures [4,5]. By integrating dynamical systems theory, numerical optimisation, and computational algorithms, nonlinear modelling and control have matured into a powerful framework capable of addressing challenges that were previously intractable using classical methods.

Equally transformative has been the rise of optimisation-driven control design within the field of nonlinear systems [6]. Modern optimisation algorithms allow engineers to compute control laws that explicitly account for constraints, uncertainties, and nonlinearities. While early applications focused on optimal feedback laws for low-dimensional systems, the field truly accelerated with the development of nonlinear model predictive control (NMPC), an approach that repeatedly solves finite-horizon optimisation problems in real time. NMPC has enabled high-performance tracking, safety enforcement, and constraint handling across a wide variety of systems, from chemical processes and autonomous vehicles to large-scale energy networks [7]. Foundational contributions in optimal and predictive control provided systematic ways to handle multivariable nonlinear systems, while advances in numerical methods and convexification techniques have made online optimisation far more tractable [8,9]. Over the past two decades, numerous studies have demonstrated the practical viability of NMPC and related optimisation-based methods, showing their effectiveness in applications with complex dynamics, strong coupling, and nonlinearity [10]. Whether implemented through gradient-based solvers, sequential quadratic programming, or learning-enhanced optimisation, these methods have reshaped modern control design and continue to inspire new research at the intersection of computation, control, and decision-making.

In parallel, performance-driven and safety-critical control paradigms have emerged as modern cornerstones of nonlinear systems engineering, particularly in robotics [11],

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autonomous systems [12], and energy management. These approaches rely on iterative computational frameworks that enforce stability and safety margins under uncertain or extreme operating conditions. They frequently incorporate nonlinear simulations, Lyapunov analysis, and probabilistic verification, all of which have become feasible only through advances in computational power and numerical algorithms. Sophisticated nonlinear models now capture complex physical interactions, actuator limits, and hybrid transitions with unprecedented fidelity. From multi-rotor drones and ground robots to flexible energy assets and distributed microgrids, computationally empowered nonlinear modelling and control have enabled reliable operation in domains where analytical solutions remain out of reach [13].

In recent years, the rapid rise of machine learning (ML) and artificial intelligence has further expanded the toolkit available to the field of nonlinear systems [14,15]. Data-driven modelling approaches such as neural networks, Koopman-based lifted models, Gaussian processes, and hybrid physics-informed learning can now approximate complex nonlinear behaviors that are difficult to capture analytically [16]. ML techniques have gained traction in tasks such as state estimation, fault diagnosis, adaptive control, and real-time prediction [17]. Unlike classical first-principles modelling, ML models can learn high-dimensional relationships directly from data, making them effective surrogates for computationally expensive simulation routines [18]. Researchers have used ML to accelerate NMPC computations, compensate for unmodelled disturbances, estimate unknown system parameters, or support digital twins operating in real time [19]. ML-enhanced models and control schemes are especially useful for handling sensor noise, unstructured environments, and time-varying nonlinearities [20]. While challenges remain regarding stability guarantees, interpretability, and robustness, the integration of AI into nonlinear system modelling and control is rapidly advancing and reshaping many engineering workflows.

Control-oriented monitoring and diagnosis frameworks also represent one of the most active research fronts. Modern systems increasingly rely on advanced observer designs, fault detection algorithms, and health-aware control to ensure safe and reliable operation [21]. With the integration of ML and high-frequency sensor data, these frameworks can detect anomalies, identify changes in system dynamics, and support predictive maintenance strategies [22]. Such advancements are essential for autonomous vehicles, industrial automation, smart grids, and other cyber–physical systems where real-time decision-making is critical [23]. Their inclusion in this Special Issue reflects the field's growing emphasis on bridging online monitoring, computational modelling, and nonlinear control synthesis.

Another important frontier in nonlinear systems engineering lies in the advancement of stochastic modelling and robust analysis techniques. Real-world systems are inherently affected by uncertainties in parameters, disturbances, and environmental conditions, making uncertainty quantification and robust control essential components of modern design workflows [24]. Approaches such as stochastic stability analysis, probabilistic reachability, and robust MPC provide rigorous ways to account for variability while ensuring performance and safety under realistic operating conditions [25,26]. In parallel, high-precision numerical methods and advanced solvers have improved the accuracy and efficiency of classical nonlinear analysis techniques, enabling the treatment of multi-scale dynamics, time delays, and hybrid switching behaviours with greater fidelity [27,28]. Together, these developments underscore the growing importance of computational innovation in advancing nonlinear system modelling and control.

Motivated by these advancements, this Special Issue, "Nonlinear System Modelling and Control", was conceived to showcase recent developments and emerging applications at the forefront of the field. The call for papers invited contributions across a broad spectrum of topics, including nonlinear modelling frameworks, advanced control strategies, distributed and networked control, observer and estimation methods, learning-based approaches, and applications in robotics, energy systems, electric drives, autonomous systems, and other complex engineering domains. Nine peer-reviewed papers that highlight important research trends are included in this Special Issue. These contributions address a wide range of topics, including advanced nonlinear modelling and estimation techniques, robust and adaptive controllers for uncertain systems, optimisation-based and data-driven methods for real-time control, and application-oriented studies that demonstrate the practical value of nonlinear system theory in modern engineering. In the following sections, we summarise each contribution to this Special Issue, situating its significance within the broader evolution of nonlinear system modelling and control.

2. Overview of the Special Issue

This Special Issue brings together nine diverse and insightful contributions that reflect the growing depth and breadth of research in nonlinear system modelling and control.

Contribution 1 ([29]). *A Finite-Time Extended State Observer with Prediction Error Compensation for PMSM Control.*

This paper proposes a finite-time extended state observer (FTESO) integrated with model predictive control (MPC) for high-performance control of permanent magnet synchronous motors (PMSMs). A disturbance-aware predictive model is constructed by incorporating lumped disturbances into the PMSM current equations, addressing load fluctuations and parameter uncertainties. The FTESO, designed with nonlinear gains and Lyapunov stability, ensures rapid disturbance estimation and is embedded into a feedforward-compensated MPC with a composite cost function considering current error and voltage increment. Simulations show that under sudden load disturbances, FTESO-MPC achieves faster recovery and a smaller steady-state error than LESO-MPC; when inductance triples, FTESO-MPC maintains smooth convergence, whereas LESO-MPC exhibits oscillations with d-axis current peaks near 200 A. Under resistance or flux variations, FTESO-MPC sustains stable regulation with less ripple, confirming its superior tracking accuracy and robustness compared to LESO-MPC.

Contribution 2 ([30]). *An Energy Saving MTPA-Based Model Predictive Control Strategy for PMSM in Electric Vehicles Under Variable Load Conditions.*

To promote energy efficiency and support sustainable electric transportation, this study addresses the challenge of real-time and energy-optimal control of permanent magnet synchronous motors (PMSMs) in electric vehicles operating under variable load conditions, proposing a novel Laguerre-based model predictive control (MPC) strategy integrated with maximum torque per ampere (MTPA) operation. Traditional MPC methods often suffer from limited prediction horizons and high computational burden when handling strong coupling and time-varying loads, compromising real-time performance. To overcome these limitations, a Laguerre function approximation is employed to model the dynamic evolution of control increments using a set of orthogonal basis functions, effectively reducing the control dimensionality while accelerating convergence. Furthermore, to enhance energy efficiency, the MTPA strategy is embedded by reformulating the current allocation process using d- and q-axis current variables and deriving equivalent reference currents to simplify the optimisation structure. A cost function is designed to simultaneously ensure current accuracy and achieve maximum torque per unit current. The simulation results under typical electric vehicle conditions demonstrate that the proposed Laguerre-MTPA MPC controller significantly improves steady-state performance, reduces energy consumption, and ensures faster response to load disturbances compared to traditional MTPA-based control schemes. This work provides a practical and scalable control framework for energy-saving applications in sustainable electric transportation systems.

Contribution 3 ([31]). *Advanced Deep Learning Framework for Predicting the Remaining Useful Life of Nissan Leaf Generation 01 Lithium-Ion Battery Modules.*

Accurate estimation of the remaining useful life (RUL) of lithium-ion batteries (LIBs) is essential for ensuring safety and enabling effective battery health management systems. To address this challenge, data-driven solutions leveraging advanced machine learning and deep learning techniques have been developed. This study introduces a novel framework, Deep Neural Networks with Memory Features (DNNwMF), for predicting the RUL of LIBs. The integration of memory features significantly enhances the model's accuracy, and an autoencoder is incorporated to optimize the feature representation. The focus of this work is on feature engineering and uncovering hidden patterns in the data. The proposed model was trained and tested using lithium-ion battery cycle life datasets from NASA's Prognostic Centre of Excellence and CALCE Lab. The optimized framework achieved an impressive RMSE of 6.61%, and with suitable modifications, the DNN model demonstrated a prediction accuracy of 92.11% for test data, which was used to estimate the RUL of Nissan Leaf Gen 01 battery modules.

Contribution 4 ([32]). *Subsequential Continuity in Neutrosophic Metric Space with Applications.*

This paper introduces two concepts, subcompatibility and subsequential continuity, which are, respectively, weaker than the existing concepts of occasionally weak compatibility and reciprocal continuity. These concepts are studied within the framework of neutrosophic metric spaces. Using these ideas, a common fixed point theorem is developed for a system involving four maps. Furthermore, the results are applied to solve the Volterra integral equation, demonstrating the practical use of these findings in neutrosophic metric spaces. These results provide foundational tools that can inform modelling, estimation, and stability analysis in practical nonlinear control applications.

Contribution 5 ([33]). *FPGA Implementation of Synergetic Controller-Based MPPT Algorithm for a Standalone PV System.*

Photovoltaic (PV) energy is gaining traction due to its direct conversion of sunlight to electricity without harming the environment. It is simple to install, adaptable in size, and has low operational costs. The power output of PV modules varies with solar radiation and cell temperature. To optimize system efficiency, it is crucial to track the PV array's maximum power point. This paper presents a novel fixed-point FPGA design of a nonlinear maximum power point tracking (MPPT) controller based on synergetic control theory for autonomous standalone photovoltaic systems. The proposed solution addresses the chattering issue associated with the sliding mode controller by introducing a new strategy that generates a continuous control law rather than a switching term. Because it requires a lower sample rate when switching to the invariant manifold, its controlled switching frequency makes it better suited for digital applications. The suggested algorithm is first emulated to evaluate its performance, robustness, and efficacy under a standard benchmarked MPPT efficiency calculation regime. FPGA has been used for its capability to handle high-speed control tasks more efficiently than traditional micro-controller-based systems. The high-speed response is critical for applications where rapid adaptation to changing conditions, such as fluctuating solar irradiance and temperature levels, is necessary. To validate the effectiveness of the implemented synergetic controller, the system responses under variant meteorological conditions have been analysed. The results reveal that the synergetic control algorithm provides smooth and precise MPPT.

Contribution 6 ([34]). *Model Predictive Control of Spatially Distributed Systems with Spatio-Temporal Logic Specifications.*

In this paper, for spatially distributed systems, we propose a new method of model predictive control with spatio-temporal logic specifications. We formulate the finite-time control problem with specifications described by SSTLf (signal spatio-temporal logic over finite traces) formulas. In the problem formulation, the feasibility is guaranteed by representing control specifications as a penalty in the cost function. Time-varying weights in the cost function are introduced to satisfy control specifications. The finite-time control problem can be written as a mixed integer programming (MIP) problem. According to the policy of model predictive control (MPC), the control input can be generated by solving the finite-time control problem at each discrete time. The effectiveness of the proposed method is presented through a numerical example.

Contribution 7 ([35]). *The Effect of Proportional, Proportional-Integral, and Proportional-Integral-Derivative Controllers on Improving the Performance of Torsional Vibrations on a Dynamical System.*

The primary goal of this research is to lessen the high vibration that the model causes by using an appropriate vibration control. Thus, we begin by implementing various controller types to investigate their impact on the system's reaction and evaluate each control's outcomes. The controller types are presented as proportional (P), proportional–integral (PI), and proportional–integral–derivative (PID) controllers. PID control was employed to regulate the torsional vibration behaviour on a dynamical system. The PID controller aims to increase system stability after seeing the impact of P and PI control. This kind of control ensures that there are no unstable components in the system. By using the multiple-time-scale perturbation (MTSP) technique, a first-order approximate solution has been obtained. Using the frequency response function approach, the stability and steady-state response of the system under the primary resonance condition, representing the worst-case resonance, are addressed. The nonlinear dynamical system's chaotic response and the numerical solution for various parameter values are also addressed. MATLAB programs are utilized to attain simulation outcomes.

Contribution 8 ([36]). *Assessment of computational tools for analysing the observability and accessibility of nonlinear models.*

Accessibility and observability are two properties of dynamic models that provide insights into the structural relationships between their input, output, and state variables. They are closely related to controllability and structural local identifiability, respectively. Observability and identifiability determine, respectively, the possibility of inferring the unmeasured state variables and parameters of a model from output measurements; accessibility and controllability describe the possibility of driving its state by changing its input. Analysing these structural properties in nonlinear models of ordinary differential equations can be challenging, particularly when dealing with large systems. Two main approaches are currently used for their study: one based on differential geometry, which uses symbolic computation, and another one based on sensitivity calculations, which use numerical integration. These approaches are implemented in two MATLAB software tools: the differential geometry approach in STRIKE-GOLDD, and the sensitivity-based method in StrucID. These toolboxes differ significantly in their features and capabilities. Until now, their performance had not been thoroughly compared. This paper present a comprehensive comparative study of these two approaches, elucidating their differences in applicability, computational efficiency, and robustness compared to computational issues. Our core finding is that StrucID has a substantially lower computational cost than STRIKE-GOLDD; however, it may occasionally yield inconsistent results due to numerical issues.

Contribution 9 ([37]). *Approximate Analytical Solutions of Nonlinear Jerk Equations Using the Parameter Expansion Method.*

The parameter expansion method (PEM) is employed to study nonlinear Jerk equations, which are often difficult to solve because of their strong nonlinearity. This method provides higher accuracy and broader applicability, enabling analytical insights and closed form approximations. This study explores the use of Prof. J. H. He's PEM to derive approximate analytical solutions of the nonlinear third-order Jerk equation, a model commonly encountered in the analysis of complex dynamical systems across physics and engineering. Owing to the strong nonlinearity inherent in Jerk-type equations, exact solutions are often unattainable. The PEM provides a simple, effective framework by expanding the solution with respect to an embedding parameter, allowing accurate approximations without the need of small parameters or linearisation. The method's reliability and precision are validated through comparisons with numerical simulations, demonstrating its practicality and robustness for tackling nonlinear problems. It is found that the parameter expansion method yields highly accurate approximate solutions for the nonlinear third-order Jerk equation, closely matching numerical simulations and outperforming several alternative analytical techniques in terms of simplicity and effectiveness. The approximate solutions derived using this method offer insights that can help control practitioners, simplify nonlinear models, and support robust controller or observer design.

3. Emerging Themes in Nonlinear System Modelling and Control

Although the contributions in this Special Issue span a wide range of systems, methodologies, and application domains, several unifying themes emerge across them. Taken together, the papers reveal how modern nonlinear modelling and control increasingly integrate data-driven methods, advanced observers, predictive and optimisation-based frameworks, and rigorous analytical tools to address uncertainty, complexity, and real-time constraints. The following subsections synthesise these cross-cutting ideas highlighting common modelling philosophies, control strategies, and application trends that collectively characterise current developments in nonlinear system research. Note that the themes discussed in the following sections reflect the contributions of this Special Issue and are not meant to represent a comprehensive survey of all modelling and control approaches for nonlinear systems. Some trade-offs are evident across the contributions. Controllers that achieve high performance or fast disturbance rejection often require more computation, while methods designed for real-time implementation may simplify models and reduce predictive accuracy. Data-driven approaches offer adaptability but must balance robustness and interpretability. Highlighting these trade-offs helps readers understand the practical strengths and limitations of the presented works.

Across these contributions, clear trade-offs emerge. For example, methods that achieve high control performance or rapid disturbance rejection often require higher computational effort or more complex observers, while approaches that emphasise real-time implementability sometimes sacrifice modelling fidelity or predictive accuracy. Similarly, data-driven models and learning-enhanced controllers offer flexibility and adaptability but must balance interpretability, robustness, and stability guarantees. Highlighting these complementary strengths and limitations helps contextualise the contributions and provides readers with a practical understanding of the design decisions inherent in modern nonlinear system modelling and control.

3.1. Modelling Approaches

A variety of modelling paradigms are represented in this Special Issue, reflecting the diversity of nonlinear systems seen in modern engineering and applied science. Several contributions advance data-driven and hybrid modelling, where computational and learning-based tools supplement classical physics-based models. For example, the deep neural network with memory features for lithium-ion battery prognosis demonstrates how latent representations and feature-enhanced learning can uncover degradation patterns not easily captured by first-principles models. Similarly, the fractional fixed-point and neutrosophic-metric-space formulation for solving Volterra equations highlights the emergence of hybrid mathematical frameworks that blend nonlinear analysis with uncertainty-aware modelling.

Reduced-order and structure-aware models appear prominently as well. Works focusing on structural observability and identifiability provide computational tools to assess whether complex nonlinear models can support reliable state and parameter estimation. Such studies are essential for large-scale systems where full-order modelling becomes intractable. Likewise, the parameter expansion method applied to nonlinear Jerk equations shows how analytical approximations can derive tractable surrogate models that retain essential nonlinear behaviour.

Across several papers, explicit treatment of uncertainties, disturbances, and parameter variations is a central theme. The finite-time extended state observer for PMSMs models lumped disturbances directly, enabling robust current prediction despite load changes and parameter drift. In energy systems, irradiance variability is captured through nonlinear MPPT models designed for digital hardware, emphasising the need for models that reflect fast-changing environmental conditions.

These modelling approaches align strongly with the computational focus of the journal: they rely on numerical optimisation, nonlinear solvers, embedded digital implementation, or simulation-driven evaluation. Collectively, the modelling contributions in the Special Issue illustrate the growing trend of integrating advanced numerical methods, machine learning, and rigorous nonlinear analysis to produce models that are accurate, uncertainty-aware, and suitable for real-time control.

3.2. Control Strategies

The contributions to this Special Issue illustrate several complementary nonlinear control strategies, each designed to address robustness, performance, and implementability in different application domains. Many papers focus on robust and adaptive control, tackling challenges such as parameter drift, disturbances, and strong nonlinear coupling. The finite-time ESO–MPC controller for PMSMs, for instance, uses a nonlinear disturbance observer to compensate for sudden load changes, achieving fast recovery and improved steady-state accuracy. Likewise, the Laguerre-based MPC method reduces the computational burden of long-horizon optimisation, enabling energy-efficient control in electric vehicle drives.

Nonlinear model predictive control (MPC) appears prominently in both methodological and application-driven settings. Beyond electric drive systems, one contribution formulates an MPC framework grounded in spatio-temporal logic specifications, demonstrating how logical constraints can be embedded into mixed-integer predictive optimisation for distributed spatial processes.

Other papers highlight continuous nonlinear control laws such as synergetic control for photovoltaic MPPT and PID-based vibration suppression. The synergetic MPPT controller offers a smooth alternative to classic sliding-mode methods, reducing chattering while preserving robustness under irradiance fluctuations. The PID vibration control study emphasises the importance of classical nonlinear control analysis resonance response, stability boundaries, and chaotic behaviour analysis within high-speed mechanical systems.

Several contributions push the boundary in terms of linking nonlinear control with computation, such as FPGA-based implementations, optimisation-enhanced observers, or hybrid control frameworks for epidemiological systems. Across the papers, the trade-offs between performance, robustness, computational complexity, and real-time feasibility remain central. Collectively, these works demonstrate that modern nonlinear control is increasingly characterised by a careful synthesis of rigorous analysis, algorithmic innovation, and hardware-aware design.

3.3. Applications and Case Studies

Beyond methodological advances, the Special Issue highlights the broad reach of nonlinear modelling and control across several impactful application domains. Power and energy systems feature prominently, with contributions on photovoltaic MPPT under variable irradiance, nonlinear control of PMSM electric drives, and lithium-ion battery health prognostics. These systems are inherently nonlinear due to electromagnetic coupling, temperature effects, and complex electrochemical dynamics. The presented control strategies ranging from predictive control to synergetic and observer-based schemes demonstrate how nonlinear methods can enable higher energy efficiency, reliability, and real-time adaptability.

Transportation and electrified mobility applications appear through advanced control of PMSMs in electric vehicles and investigations relevant to maritime and autonomous systems via battery prognostics and digital twin-inspired modelling frameworks. These contributions underscore the importance of nonlinear control in ensuring safe, efficient, and disturbance-resilient operation in dynamic environments.

This Special Issue also includes application studies in mechanical systems, where PID-based vibration control is validated through analysis of resonance, stability, and chaotic behaviour. Across the applications, validation ranges from detailed numerical experiments to FPGA-based hardware tests and real-world datasets. Collectively, these case studies highlight the significance and applicability of nonlinear modelling and control in addressing real-world challenges related to safety, sustainability, and resilience.

4. Bridging Theory, Computation, and Real-World Deployment

The contributions in this Special Issue collectively underline the increasingly critical link between theoretical nonlinear systems research, computational tools, and practical deployment in real-world systems. Across many papers, the role of advanced numerical methods and optimisation frameworks is explicit. Model predictive control relies on efficient solvers, mixed-integer programming, and reduced-order parametrisations such as Laguerre functions to satisfy real-time requirements. Nonlinear observers, such as finite-time ESOs, also depend on careful numerical tuning and stability analysis to perform reliably under rapidly varying conditions.

The synergy between high-fidelity models and real-time feasibility is a recurring theme. Battery RUL estimation and MPPT control demonstrate how learning-enhanced or synergetic models can produce accurate predictions while remaining computationally tractable for deployment on embedded platforms. FPGA-based implementation of nonlinear controllers further highlights the importance of hardware-aware design, where sampling rates, fixed-point arithmetic, and power constraints shape the controller architecture.

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Several contributions align with the broader vision of digital twin systems, where accurate modelling, estimation, and prediction enable online monitoring and decision support. Although digital twins are not explicitly developed in the papers, many contributions such as battery ageing models, observer-based PMSM estimation, and spatio-temporal logic MPC provide the foundational elements necessary for building real-time intelligent system representations.

Time delays, communication constraints, and robustness are addressed in MPC, observer design, and parameter identification studies. These factors are essential for cyber–physical systems such as electric transportation, renewable energy assets, and distributed sensing networks. This Special Issue reinforces that nonlinear modelling and control sit at the core of efficient, safe, and sustainable operation. As systems become more electrified and interconnected, the need for robust nonlinear models, real-time observers, and predictive controllers will continue to grow. The contributions in this issue illustrate the increasing integration of theory, computation, and practical implementation, moving the field closer to dependable and intelligent real-world nonlinear control systems.

5. Open Challenges and Future Directions

While the papers in this Special Issue make significant advances, several open problems remain at the frontier of nonlinear system modelling and control. Scalability remains a central challenge, particularly for large-scale nonlinear systems such as multi-energy networks, autonomous-vehicle fleets, or epidemiological systems with spatial heterogeneity. Methods such as spatio-temporal logic MPC and structural identifiability analysis offer promising directions, but further progress is needed to extend nonlinear control to systems with high dimensionality and interconnection complexity.

Building on these challenges, several near-term research priorities emerge in the field of nonlinear systems. These include improving scalability and computational efficiency for high-dimensional and interconnected systems; integrating robust and learning-enabled control while ensuring stability, interpretability, and safety; and developing hardware-aware real-time implementations for embedded platforms or FPGAs. Establishing standardised benchmarking protocols and openly available datasets such as battery cycle-life datasets for predictive control or PV system datasets for MPPT evaluation can further accelerate progress and enable systematic comparison of new methods.

Robustness under uncertainty continues to be an important concern. The papers in this issue highlight the impact of parameter variability, disturbances, and environmental fluctuations. The finite-time observer and synergetic MPPT controller address these aspects, but a more unified framework that integrates robust optimisation, adaptive estimation, and stochastic modelling remains an open direction. The integration of learning-enabled control presents opportunities and risks. Battery RUL estimation demonstrates the power of deep learning for complex nonlinear systems, but ensuring stability, safety, and interpretability in learning-based controllers remains a challenge. Safe reinforcement learning, certifiable neural-network approximations, and verifiable learning architectures represent promising research avenues. Hybrid and cyber–physical systems pose ongoing challenges due to switching dynamics, mode-dependent behaviours, and digital/physical interaction layers. Applications such as vibration control and epidemiological modelling show the importance of addressing nonlinear dynamics under changing conditions. Future work must consider cyber-security, resilience to sensor and communication attacks, and fault-tolerant nonlinear control. Achieving real-time computation for advanced nonlinear control laws is another critical area. MPC with spatio-temporal logic, high-order observers, and nonlinear optimisation must meet tight computational budgets on embedded or resource-constrained hardware. Research in algorithmic acceleration, reduced-order models, surrogate solvers, and hardware-aware control code generation will remain crucial. Finally, the field lacks standardised benchmarks and openly available datasets for the systematic evaluation of competing nonlinear modelling and control methods. While existing battery and power electronics datasets provide useful starting points, the development of broader, community-accepted benchmarks would significantly enhance comparability and accelerate progress. From a societal perspective, nonlinear modelling and control will play a key role in addressing sustainability, energy transition, and resilient infrastructure. Electrified transportation, renewable generation, and smart autonomous systems all rely on accurate nonlinear models and robust controllers. The contributions in this Special Issue point toward these broader impacts and motivate continued innovation in the years to come.

6. Concluding Remarks

This Special Issue on "Nonlinear System Modelling and Control" presented nine contributions advancing the theory, computation, and applications of nonlinear systems, spanning topics such as advanced observers, model predictive and vibration control, MPPT design, identifiability analysis, learning-based battery prognosis, and analytical methods for nonlinear differential equations. Common themes include the integration of physics-based and data-driven modelling, control strategies balancing robustness and computational feasibility, and applications across energy systems, electrified transport, and mechanical systems, while also highlighting ongoing challenges in scalability, real-time implementation, uncertainty management, and the reliable deployment of learning-enabled controllers.

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