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Editorial

Robust Control as a Mathematical Paradigm for Innovative Engineering Applications

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Robust control is a mathematical paradigm for innovative engineering applications. It is based on the feedback control principle, which is the basis for most control systems. Feedback control systems are used to regulate the behavior of a system by using feedback from the system itself. Feedback is used to adjust the system to behave in a desired manner. Robust control takes this principle one step further by using feedback to regulate the system's behavior and to make the system more resistant to changes in its environment. This makes the system more adaptable and able to cope with changing conditions. Robust control systems are primarily concerned with making decisions, deciding how an operation can be performed given its environment, how it should operate given its environment, and ensuring that its actions satisfy specific goals. Mathematically, they are concerned with predicting the future states of the system that delivers decisions to make optimal decisions when faced with uncertain or unknown future states.

Robust control is a powerful tool that can be used to enhance the performances of engineering systems. There are many benefits to using robust control, including improving system performances, handling uncertainty and disturbances, reducing sensitivity to changes in a system's parameters, and improving system stability. Robust control can be used to improve the performance of a wide variety of engineering systems, from simple mechanical systems to complex electrical and electronic systems. In many cases, robust control can significantly improve system performances with little effort. By using robust control methods, engineers can design systems that are less likely to be influenced by external factors, including noise and vibration. This can lead to improved system performance and reliability. Additionally, robust controls can be used to design systems that are more resistant to changes in operating conditions. This can be especially beneficial for systems that operate in harsh or hostile environments. Ample research has been conducted on this topic. Therefore, the purpose of this literature review is to present the importance of robust control as a tool for any engineer who wants to improve the performance of their systems. The selected papers represent recent advancements in the field of engineering mathematics with a particular focus on possible applications

Elsisi et al. (2021) conducted a study to improve voltage regulation in power systems in the presence of uncertainty. The proposed framework uses optimization algorithms to predict the voltage and focuses on a robustness property that can be achieved by employing nonlinearity in the model. On the basis of optimization techniques, a robust predictive controls paradigm for automatic voltages regulators against uncertainty has now been developed. A model predictive controller (MPC) is designed to achieve robustness relative to time-varying disturbances and the imperfection of input signals that vary discontinuously at the measuring instants. This scheme showed that a wide range of constant-time control actions could be implemented in an MPC framework [1]. The established design offers independent tracking abilities for two input strategies: first-order difference techniques and zero lag strategies. Such tracking abilities decrease the risk of overshoot problems introduced by using zero lag responses in the presence of reference disturbances or switched DC voltage sources. A new methodology has been proposed that extracts only one of those two responses while keeping its other parts intact. The theoretical model described in the article describes the probabilistic nature of the voltage regulator's performance regarding the switching frequency, amplitude, and phase angle (or voltage angle between the zero-to-peak and maximum negative values). Thus, the response times can be increased by a factor of up to 2, whereas traditional approximation techniques do not provide such an increase. Furthermore, the proposed scheme incorporated an optimizer with higher accuracies.

In a study, Pujol-Vazquez et al. (2020) discussed a robust control design for a system with time delay measurement feedback and endogenous perturbations [2]. Pujol-Vazquez et al. (2020) investigate the robust controls design for Furuta's system with time-delay measurement feedback and exogenous-based perturbations. The authors discuss robust control design techniques such as (1) the integrating approach, (2) linearization approaches, and (3) the direct principle of controller methods. This study focuses on cases where the plant has a phase setpoint; some previous studies have shown that there is still room for improvements in designing the controller for this case. Therefore, we focus on designing a robust controller for this case by using different optimal learning algorithms discussed in this paper to improve our designs. Under accurate measurements, the proposed control system can achieve higher performance results than other alternative solutions. However, even with accurate measurements and the enhanced robustness of the Furuta system, it is still vulnerable to external disturbances (Pujol-Vazquez et al., 2020). By adding delays on feedback signals and imposing exogenous perturbations, this paper provided a solution that effectively addresses the fidelity problems of the Furuta approach and limitations imposed by external disturbances.

According to Şuşcă et al. (2021), the unified analysis, control, and design (UACSD) concepts are important for designing safe, exhaustive, and cheap hybrid control strategies for DC-to-DC converters. The hybrid strategy includes both predictive and reactive approaches. The study starts with a general introduction to the UACSD concept. Then, they explain the advantages and disadvantages of such an approach in similar studies. The authors showed how it could be used to create an interoperability framework between different code generators used in domain-specific software development tools. Next, they described how this approach could be used, in addition to inspirational generated controllers by including features, such as filtering, or adaptation techniques, such as prediction error minimization compensators, that allow us to minimize system energy losses due to an internal fault or inaccuracy in model parameters [3]. The study analyzed the Unified CACSD Toolbox, which consists of the CACTOOL library and four mathematical tools (attention-based Hamiltonian optimal controller synthesis, robust AHC controller synthesis, hybrid simulation, and robust controller synthesis), which are used to develop robust and efficient hybrid control designs for DC-to-DC power converters. The authors found that when designing a composite controller, one needs to specify both severe-condition and smooth-channel models at each level of the functional hierarchy they consider. Therefore, a unified approach toward model specification and controller design techniques can be applied to different problem domains. Finally, the authors exemplified their approach via its application to the design of beefed-up switch-mode controllers.

Similarly, Mihaly et al. (2021) presented a robust controller design method for fractional-order systems. The method, called μ-synthesis, is based on the idea of using a fractional-order transfer functions in the feedback loop of a controller [4]. The authors showed that this approach could be used to design robust controllers for parametric uncertainties and disturbances. Furthermore, the authors demonstrate the effectiveness of the μ-synthesis method using a series of simulations. Mihaly et al. (2021) proposed a robust control framework based on μ-synthesis, which can generate prediction uncertainties directly without prior knowledge of the system's state. The authors clarified that their algorithm works well in practice, achieving good performance with minimal computational effort. This research presented a new mathematical formulation and stochastic approach to robust control, which is resolved by a new set of dual variables and their corresponding distributions. These are found to be particularly effective in the context of fractional-order systems with time-varying states. Thus, the analysis of the stochastic approach is presented, along with an existing result on their stability.

Saenz-Aguirre et al. (2020) highlighted the findings of a study on the robust stability of a wind turbine pitch control system [5]. The study used the Kharitonov theorem to analyze the system's stability under various conditions. The article investigates the robust stability analysis of a wind turbine pitch control system with an asymmetric rotor. The mathematical model is based on the Kharitonov theorem, which gives the fastest algorithm for finding an unstable equilibrium point around any given starting point in a dynamic system. The dynamic system models the aerodynamic characteristics of the wind turbine. It includes two main parts: the rotor disc, which represents a flexible blade with an airfoil-like contour, and a fixed contact element on top of it. This paper will be helpful for engineers when designing wind turbines that need to analyze systems to improve efficiency or design better models to determine stability characteristics. The Kharitonov theorem assumes that the multiplier is bounded; therefore, this technique cannot analyze many practical scenarios. The study's results showed that the pitch control system is robustly stable under various conditions. The authors also introduce a modified Kalman-filter technique, which generates a stable control law with high gain and provides stability guarantees for wind turbine pitch control systems.

In their study, Yañez-Badillo et al. (2021) aimed to implement a quadcopter with different autonomously controlled behaviors [6]. In this paper, the authors use artificial neural networks (ANNs) to classify sensor inputs as motor outputs, which are then processed using particle swarm optimization (PSO). These experiments applied to various environments: urban traffic in Madrid, indoor terrain in Villegas, intelligent transportation in Barcelona, and outdoors in Maracena. The researchers developed an algorithm consisting of four main steps: (1) preprocessing, (2) detection, (3) classification and estimation, and (4) optimization. Collecting experimental results from different sources, they improve control strategies for novel autonomous movement architectures created by ANNs towards robust motion control for modern flying quadcopters. The adaptive robust motion controls of quadrotor systems using artificial neural networks and particles swarm optimization is proposed (Yañez-Badillo et al., 2021). The scheme learns the angular orientation of the robotic arm in real time, using a quadrotor with precise position and orientation sensors as the target. The system achieves better results than standard models without increasing computational complexity. The authors described a method for the motion control of quadrotor systems that use artificial neural networks and particle swarm optimization. These techniques allow them to train and tune their networks by feeding the training data with labeled data and testing the network on an unseen domain (Yañez-Badillo et al., 2021). The results showed that the trained network can perform well in 3D unstructured domains, even without prior knowledge about its learning ability. The adaptive robust and robust control systems implemented using artificial neural networks and particle swarm optimization are studied to demonstrate the ability of these algorithms to generate a robust control signal capable of adapting over time. The authors also showed that these adaptive algorithms could be extended to include overhead trajectories by incorporating new rules into the network.

In conclusion, it is noted that this robust model is a powerful tool that can be used to predict the behavior of complex systems. The model is based on a set of simple rules that govern the interactions between system elements. The model can capture the essential features of the system and can provide accurate predictions about the system's behavior. Additionally, the model can help businesses and organizations make better decisions when it comes to their finances.

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