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# TIME DELAY SYSTEMS AND DATA COMMUNICATION NETWORKS: (AN INVESTIGATING STUDY ON THE IMPACT OF UNCERTAINTY BLOCKS)

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**Abstract**

*The impact of uncertainty blocks on time delay systems is the main subject of this research, which explores the complex dynamics of data communication networks. Within the field of computer science, the research delves into the difficulties presented by uncertainty blocks in the context of time delays, with the goal of elucidating their effects on the general effectiveness and dependability of data transmission networks. To maintain competitiveness in the markets for auxiliary services (such frequency regulation and load following), a highly distributed and networked communication system must be developed. Robust controller architecture with several unknown time-varying delays is considered for flow control problems. While the major focus is on data-communication networks, other flow control problems can also be solved with the suggested approach, and it can even be extended to problems involving several unpredictable time delays. This paper presents a PD controller for Networked Control Systems (NCS) with delay. The primary causes of the issues with networked control systems (NCS) are delays in data transfer via the communication network. A comparative performance analysis for different network delays is carried out. In order to simulate an AC servo motor control system, this study uses the Controller Area Network (CAN-Bus) as the communication network medium. MATLAB True Time package is used in the simulation to investigate the effects of different delays. The results of this study advance the field of computer science by illuminating these crucial elements and deepening our understanding of the complex nature of time delay systems in data communication networks. They also offer insightful information for the creation of reliable and resilient communication protocols.*

**Keywords:** *Data communication, Time delay system, Uncertainty block, Networked control systems.*

## 1. INTRODUCTION

Data communication has been increasingly integrated into our daily lives due to the unstoppable expansion of the digital age. Information flows between countries, directing our interactions, supplying energy to our enterprises, and reshaping the globe. However, beneath the surface of this apparently smooth flow is a convoluted web of interconnected networks that are subject to complex protocols and suffer inherent difficulties. One such difficulty that frequently lurks in the background is the constant threat of ambiguity.

Time-delay systems' mysterious 'uncertainty blocks' have a lasting and disruptive influence on the delicate dance of data transfer. Envision a digital thoroughfare teeming with data packets, each containing a crucial piece of the larger picture. These packets run against uncertainty blocks in the network, which are obstacles like erratic jitter, variable delay, and erratic packet delivery. Similar to potholes on the digital highway, these interruptions have the potential to seriously impair communication, resulting in delays, tainting data, and eventually impeding the fundamental functions of a networked society (singh;2022).

Uncertainty barriers have an effect that goes beyond simple annoyance. Businesses suffer financial losses, brand harm, and lost productivity as a result of slow and unreliable data sharing. Information that is misplaced or delayed in essential infrastructure can have disastrous effects and endanger national security as well as public safety. Even in our private life, a shaky video chat or a slow online game might cause us to feel alone and frustrated.

Thus, it is not just a theoretical endeavour to look into how uncertainty blocks affect time-delay systems in data communication networks. It is an effort to uncover the obscure gaps in the digital highway, comprehend the complex dance between interruption and delay, and eventually open the door for a more dependable and robust communication infrastructure. This research dives into the core of this problem, seeking to clarify the nature of uncertainty blocks, measure their influence on various network protocols and applications, and investigate possible solutions. We can attempt to change uncertainty from a disruptive enigma into a manageable factor by using rigorous analysis, creative engineering solutions, and a thorough understanding of the underlying dynamics. This will guarantee that the information highway continues to run smoothly, effectively, and openly for everyone.

The primary focus of this study is controller design for reducing different types of communication delays that arise in the networked control system. The networking technique used is called CAN Bus. The control law of the suggested discrete time PD controller is designed with consideration for the effects of delay parameters inside the network. The control law of the suggested discrete time PD controller was designed with consideration for the delay parameters of the network. There are three situations in which this controller is used: (i) optimal network performance; (ii) output response with different time delays.

### 1.1. Significance of Time Delay in Data Communication Networks

Often a silent character in the big opera of data communication, time delay is the conductor of the whole show. It shapes the features of dependability, guaranteeing that info arrives entire, and it paints the hues of responsiveness, characterising how quickly your clicks reverberate on the screen. Every aspect of network communication is affected by it, from the quick flick of a video conversation to the pulsating heart of real-time apps. Response times stutter when delays occur, turning conversations into sluggish nightmares and endangering the delicate ballet of information sharing. Enterprises experience the pain of reduced efficiency and diminished confidence, as vital infrastructures hover near the brink of collapse. However, there is a secret harmony beneath this seemingly chaotic power. Like expert musicians, controlled delays smooth out data bursts, keep the network calm, and even synchronise time-sensitive processes over long distances. The actual skill of building robust and dependable networks is realising this duality and becoming proficient in the tempo of time delay. Because the secret to a smooth information flow, encouraging smooth relationships, and realising the full potential of our digital world lies in the harmonious fusion of speed and stability.

### 1.2. Objectives of the study

- To systematically characterise uncertainty blocks in data communication networks' time delay systems in order to comprehend their causes and effects on network performance.
- To create and evaluate reliable controllers for flow control issues with unknown time-varying delays, taking into account situations outside of data transmission networks.
- Using the CAN-Bus communication channel, a comparative analysis for different network delay scenarios will be conducted in order to evaluate the efficacy of a PD controller in Networked Control Systems with communication delays.

## 2. REVIEW OF LITERATURE

**Chen et al. (2023)** This work addresses the control problem for a particular class of cyber-physical systems (CPSs) that are subject to external threats, time delays, and nonlinearities. The authors suggest an adaptive robust neural control approach to counter state limitations and unknown time-varying deception attempts. It makes use of barrier Lyapunov functions and dynamic surface approaches. This paper provides important insights for control of complex networked systems under uncertainties by highlighting the critical role of neural networks in approximating unknown nonlinear factors and the efficacy of dynamic surfaces in reducing the computational complexity of backstepping.

**Dileep (2020)** This thesis explores large-scale systems with time delays that are intrinsic and interrelated subsystems. Using frequency-domain and Lyapunov-based methodologies, the author creates resilient decentralised control systems that manage uncertainty and sustain stability even when there are delays. When it comes to creating resilient networks with distributed control structures, this research is very pertinent as it offers useful tools and approaches for addressing the decentralised control challenge.

**Rashid et al. (2023)** suggested a sophisticated distributed H∞ control technique designed for large-scale, unpredictable, networked time-delayed systems. The study's applicability to the energy industry is demonstrated by its publication in Energy Reports. Enhancing control system robustness in the face of uncertainty is the main goal of their work, which makes it especially appropriate for applications in dynamic and complex contexts. In an effort to increase performance and stability, the authors make changes to the current H∞ control system. While admitting the uncertainty inherent in large-scale systems, Rashid and colleagues' study addresses the difficulties associated with interconnected systems. Since many real-world systems include delays in their dynamics, adding time delays to their analysis gives them a more realistic touch. Robustness is emphasised in the suggested strategy, which is an important factor in guaranteeing the stability and dependability of networks. The technique is a noteworthy contribution to the area as it offers a comprehensive solution to manage uncertainties and disturbances by combining H control concepts.

**Schiffer et al. (2017)** examined the resilience of distributed averaging control in power systems while taking dynamic communication topology and time delays into account. Their paper, which was published in Automatica, examines the difficulties posed by different network topologies and communication delays in the setting of power systems. In power systems, the distributed averaging control technique is frequently used to help distributed agents come to a consensus. Still, a crucial factor to consider is how time delays and changing communication topologies affect how reliable this control strategy is. The study by Schiffer and colleagues emphasises how critical it is to comprehend how communication topology dynamics and time delays affect distributed control's performance and stability in power systems. The paper adds significant knowledge for developing robust and adaptive control systems in power system applications by shedding light on the resilience of distributed averaging control.

**Tasoujian's (2020)** For uncertain time-delay systems, research focuses on linear parameter varying (LPV) control techniques. The study specifically uses these control strategies to address the difficult issue of automated blood pressure regulation. The article, which was published in an undisclosed journal, discusses the challenges of modelling and managing physiological systems with a focus on the function of LPV control in managing uncertainties and delays. The Tasoujian study emphasises how important it is to take unpredictable factors into account when designing time-delay systems, particularly in the crucial area of automated blood pressure regulation. Improved control performance and patient safety are enhanced by the adaptable framework that LPV control offers in response to changing system conditions. This research provides important insights into the implementation of advanced control techniques for healthcare-related systems by addressing the unique issues in the medical area.

**Zeng et al. (2020)** Their research, which was published in Applied Mathematics and Computation, provides insights into the stability of sampled-data systems with time delays. The study looks into the stability characteristics of systems that experience temporal delays and sampling effects, which are common in a lot of real-world control applications. Designing effective control techniques for sampled-data systems requires an understanding of how time delays and sampling intervals interact. Zeng and colleagues' research adds significant information to the field of stability analysis of sampled-data systems, making it applicable to a wide range of engineering applications. The results of the study aid in the creation of strong control schemes that take into account the complex dynamics brought about by sampling and temporal delays. Such understandings are essential for developing control systems in real-world situations where intrinsic delays and discrete-time measurements are inescapable.

## 3. PROPOSED METHOD

In the design of control systems, the motor is commonly utilised as an actuator. The The plant in this paper's simulation is a two-phase AC servo motor. The two-phase ac servomotor is without a doubt the most widely used type of servomotor. With two stator coils positioned "90" electrical degrees apart and a high-resistance rotor, the ac servomotor is a two-phase induction motor. A control signal is applied to one phase, and a fixed signal, phase-shifted by 90 degrees with regard to the control signal, is applied to the reference winding. The majority of uses for the motor are low-power ones. The reference filed voltage is denoted as er(s) (s), and the control filed voltage is labelled as Vc. The torque generated by this motor depends on Vc(s), er(s), and the sine of the angle formed by er(s) and Vc(s). The transfer function of the motor is usually:

$$\frac{\theta(s)}{V_c(s)} = \frac{K_m}{s(\tau s+1)} \quad \textbf{(1)}$$

When used as a plant in NCS, the servo motor's transfer possibilities are

$$Gp(s) = \frac{1000}{s(s+1)} \quad \textbf{(2)}$$

### 3.1. Measurement of PD Gain

The PD (Proportional-Derivative) Controller is the control mechanism employed by the controller node in this simulation. Thus, a controller parameter is required for calculation. The transfer function of the controller is

$$G_c = K_p + K_d s \quad \textbf{(3)}$$

The plant in this study is the AC servo motor from the Simulink model. The transfer function of the motor is shown in (2). Initially, the P controller's gain Kp is considered by:

$$Gp(s) = \frac{1000}{s(s+1)} \times K \quad \textbf{(4)}$$

The problem is transformed into a characteristic equation, and it can be solved by applying the root criteria. The gain kp value for the controller p needs to be higher than zero (kp>0). Next, the PD controller gain is computed using

$$G(s) = \frac{1000}{s(s+1)} \times (K_p + K_d s) \quad \textbf{(5)}$$

**Table 1:** PD Controller Parameters

| Parameter | Meaning | Values | | | |
|---|---|---|---|---|---|
| | | Case I | Case II | Case III | Case IV |
| $K_p$ | Proportional Value | 3 | 1.7 | 1.7 | 1.7 |
| $K_D$ | Differential Value | 0.04 | 0.04 | 0.037 | 0.07 |

### 3.2. NCS Simulink Model based on the CAN Bus

Networked control systems based on CAN buses can be simulated with Matlab/Simulink and the TRUETIME toolbox. Because TRUETIME takes into account the effects of control task execution and data transmission on the dynamics of the controlled system, it is a valuable tool for experimental research on dynamic real-time control systems.

It provides computer and network blocks, such as scheduling policies, controller tasks, network interface responsibilities, input/output activities, and message transmission, that let users specify which threads should be run. Researchers can study compensation schemes that adjust the control algorithm based on real timing variation observations thanks to TRUETIME.

The CAN-based networked control system model of the simulation platform is based on a DC motor that is connected to CAN and operated by one controller node using the PD control algorithm. The controller parameter testing for simulation is displayed in Table 1.

## 4. SIMULATION RESULTS

The simulation is run using the specifications and simulation settings for this network. Below is a list of them.

- The system: CAN BUS
- Data Rate: 80000 bits per second.
- 40 bits minimum frame size
- Loss chance is zero.
- Sampling interval: 10 milliseconds (h)

Since single-rate NCS is used throughout the simulation, the sample intervals for the sensor, controller, and actuator are all the same. The PD controller is composed of the two tuning parameters, Kp and Kd, as was previously explained. The timing of the servo motor and the reference input signal are compared for different controller parameters in Figures 1 and 4. Table 2 displays the results of simulations with various controller parameters. These results indicate that instance 3 has less overshoot than cases 1 and 2. Fig. 4 displays the simulation result for scenario 4 parameter. In this case, the output is underdamped. 4. The simulations' worst-case scenarios are as follows. And the best result is obtained from the parameter simulation results of case 3. In all four cases, the outcome of scenario 3 is the most suitable. Following proper tuning, the values of the PD controller parameters were Kp = 1.7 and Kd = 0. 037. This value is selected in order to examine the second delay task between the sensor and controller. Based on the simulation's findings, the CAN bus's data speed or baud rate can be changed to calculate the network latency. The response time of the system is compared in the following figures.

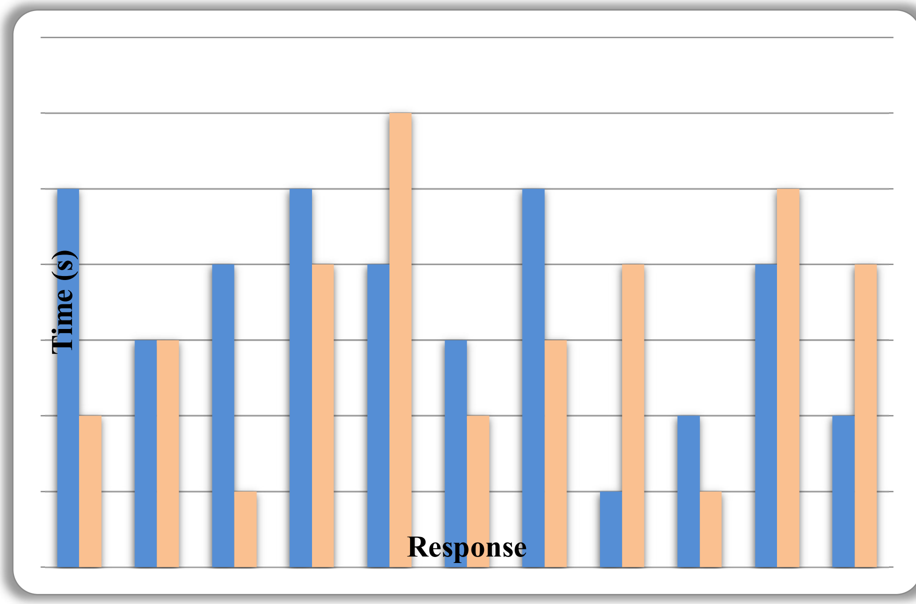


**Figure 1:**Results of Case 1 PD parameter in the Simulation

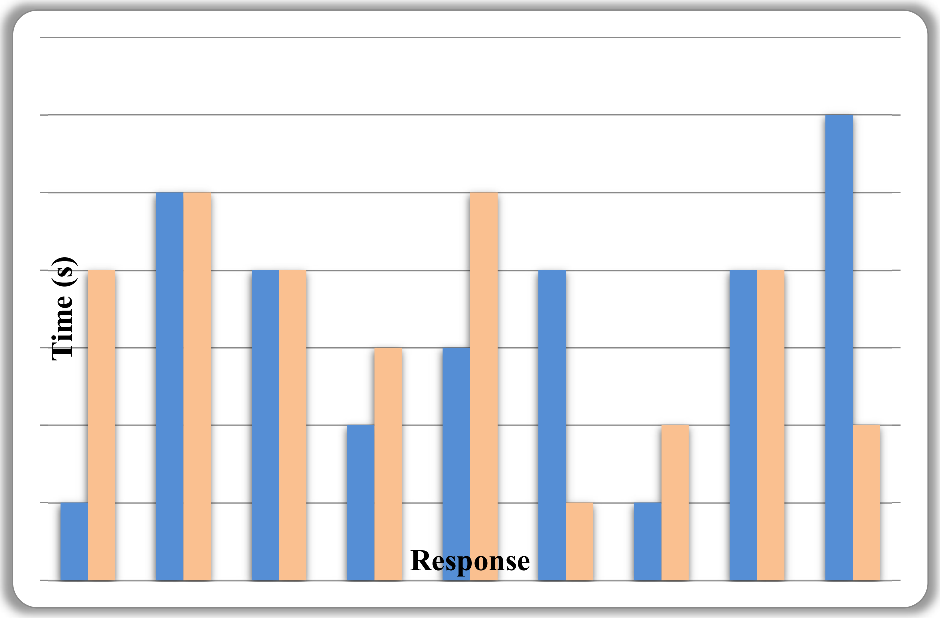


**Figure 2:**Simulation results for PD parameters in Case 2.

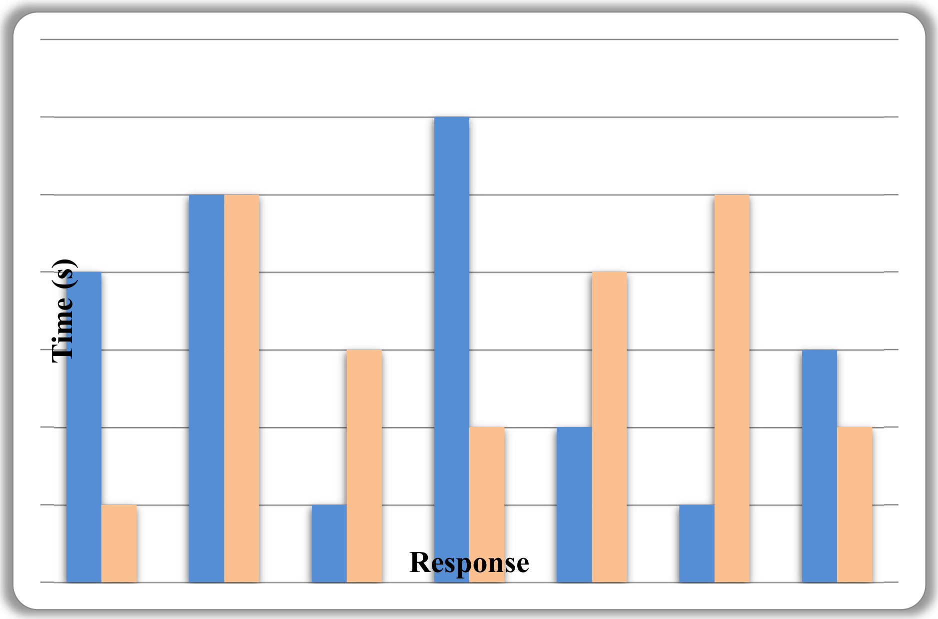


**Figure 3:**Case 3: Simulation Results for PD parameters

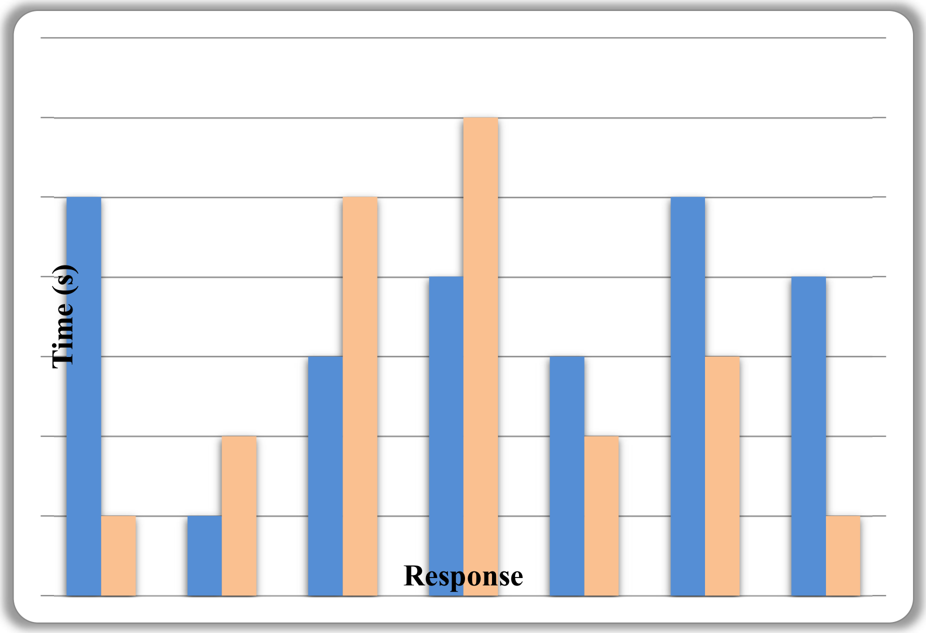


**Figure 4:**The Case 4 PD Simulation's Outcomes

Table 2 uses CAN BUS as a networked medium to compare how the servo motor responds to different delay scenarios. Time domain metrics including rising time, peak overshoot, and settling time are utilised to compare. Pacifications have been determined throughout by using the graph.

**Table 2:**Results of Comparing PD Controller Parameters

| **Case** | **PD Parameters** | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| Rise time | 0.30s | 0.25s | 0.25s | 0.26s |
| Overshoot | 2.5 | 4 | 1.5 | - |
| Setting Time | 0.50 | 0.44 | 0.40 | - |
| Performance | Bad | Good | Better | Bad |

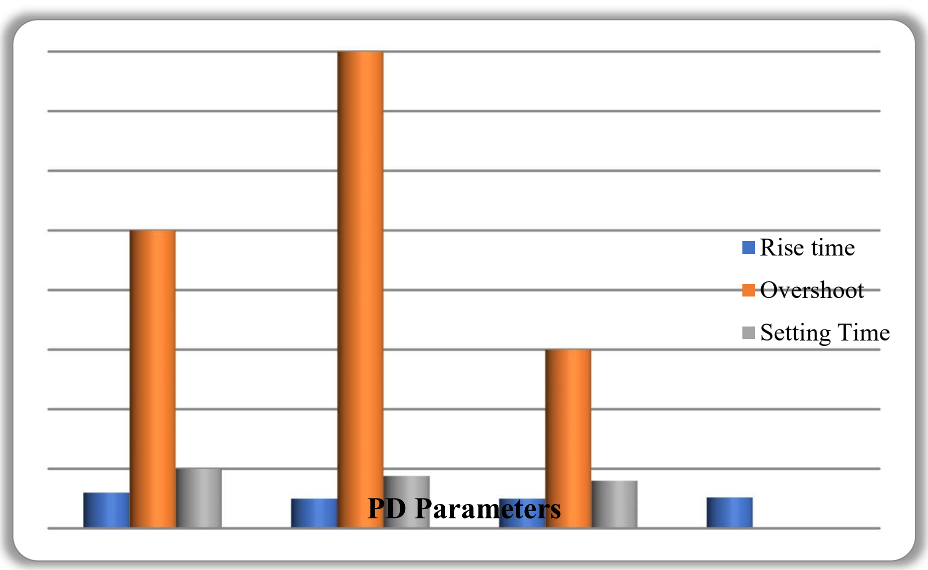

**Figure 5:**Comparing the PD controller parameter results graphically

## 5. CONCLUSION

The shadow of uncertainty blocks, which lurk within time-delay systems and threaten to sabotage the delicate dance of information flow, grows with our reliance on data communication networks. By delving into the core of this mystery, this work has illuminated the effects of these disruptive malfunctions and opened the door to a more stable and resilient future. As an example of systems with multiple time delays, we examined the flow control problem in this research in a data communication network that involves several time-varying uncertain time delays in separate channels. The sensor-controller latency can be examined using the simulation results. Based on the results, examine how the delay affected the operation of the control system. The impact of CAN transmission speed and performance on CAN network delay is concluded. It should be mentioned that the present method might be extended if there are more output channels with similar time delays. Therefore, any integrating system with input or output channels that have several unknown time-varying delays can be controlled using our method. This work contributes to the growth of computer science in general by improving our understanding of the difficulties present in time delay systems inside data communication networks and providing critical insights for the creation of reliable communication protocols.

## 6. FUTURE SCOPE

The theory of dissipative systems has shown to be a valuable tool in both nonlinear system control and stability analysis. Stability problems are solvable if dissipativity is guaranteed. The creation of passivity in electrical networks and other dynamic systems containing dissipative energy is known as dissipativity. It has therefore been effectively used in many domains, such as robotics, circuits, systems, control theory, and applications. However, very little attention has been paid to the systematic study of the dissipative control problem of discrete-time switched NNs with time-varying delays, which will be the subject of our future research.

## REFERENCES

1. *Alsabah, M., Naser, M. A., Mahmmod, B. M., Abdulhussain, S. H., Eissa, M. R., Al-Baidhani, A., ... & Hashim, F. (2021). 6G wireless communications networks: A comprehensive survey. Ieee Access, 9, 148191-148243.*

2. *Ayaz, S. B., Tian, H., Gao, S., & Fisher, D. L. (2023). Proactive route choice with real-time information: Learning and effects of network complexity and cognitive load. Transportation Research Part C: Emerging Technologies, 149, 104035.*

3. *Ballam, R. (2023). Consensus of multi-agent systems with communication uncertainties (Doctoral dissertation, Queensland University of Technology).*

4. *Banks, H. T., Hu, S., Ito, K., Li, Z., & NORTH CAROLINA STATE UNIV AT RALEIGH. (2015). Uncertainty in Damage Detection, Dynamic Propagation and Just-in-Time Networks.*

**5.** *Chen, Z., Wang, X., Pang, N., & Shi, Y. (2023). Adaptive Resilient Neural Control of Uncertain Time-Delay Nonlinear CPSs with Full-State Constraints under Deception Attacks. Entropy, 25(6), 900.*

**6.** *Dileep, D. (2020). Design tools for the robust decentralized control of large-scale systems with time delays (Doctoral dissertation, Ecole Centrale Lille, France; KU Leuven, Belgium).*

**7.** *Hasan, M. A., Oglah, A. A., & Marie, M. J. (2023). Time delay effect reduction on the wireless networked control system using an optimized FOPI-FOPD controller. International Journal of Power Electronics and Drive Systems (IJPEDS), 14(2), 852-862.*

**8.** *Hikichi, Y., K. Sasaki, R. Tanaka, H. Shibasaki, K. Kawaguchi, and Y. Ishida (2013). A discrete pid control system using predictors and an observer for the influence of a time delay. International Journal of Modelling and Optimization, 3(1), 1–4.*

**9.** *Ikeda, Kazushi, et al. "Twitter User Profiling Based on Text and Community Mining for Market Analysis." Knowledge-Based Systems, vol. 51, Elsevier BV, Oct. 2013, pp. 35–47. Crossref, https://doi.org/10.1016/j.knosys.2013.06.020.*

**10.** *Pan, D., & Wu, Z. (2021, May). Consensus for Discrete-Time Multi-agent Systems with Time Delays and Parameter Uncertainties under False Data Injection Attacks. In 2021 IEEE 4th International Conference on Electronics Technology (ICET) (pp. 1304-1311). IEEE.*

**11.** *Rashid, S. M., Ghiasi, A. R., & Ghaemi, S. (2023). An improved robust distributed H∞ control method for uncertain interconnected large-scale time-delayed systems. Energy Reports, 10, 2374-2393.*

**12.** *Schiffer, J., Dörfler, F., & Fridman, E. (2017). Robustness of distributed averaging control in power systems: Time delays & dynamic communication topology. Automatica, 80, 261-271.*

**13.** *Sharma, P., & Neeli, S. (2023). Computation of stability boundary locus of robust PID controller for time delayed LFC system. International Journal of Dynamics and Control, 1-11.*

**14.** Singh K. Abhishek (2022); Communication Laws and Digital Media Contents-A Critical Evaluation (With Particular Reference to Social Media vs. Freedom of Expression); NeuroQuantology; 20(19) pp. 1193-1199;
DOI: 10.48047/nq.2022.20.19.NQ99111

**15.** *Srivastava, A., Negi, R., & Kar, H. (2023). Guaranteed Cost Control for 2-D Uncertain Discrete State-Delayed Systems in Roesser Model Employing Actuator Saturation. Circuits, Systems, and Signal Processing, 1-29.*

***16.*** *Tasoujian, S. (2020). Linear Parameter Varying Control of Uncertain Time-Delay Systems with Applications to Automated Blood Pressure Regulation.*

***17.*** *Tian, Y., Yin, Y., Wang, F., & Wang, K. (2022). Impulsive Control of Complex-Valued Neural Networks with Mixed Time Delays and Uncertainties. Mathematics, 10(3), 526.*

***18.*** *Urban, M., M-Blaho, M. Murgas, and M. Foltin (2011). Simulation of networked control systems via truetime. Technical Computing Prague, 1(1), 1–7.*

***19.*** *Yang, Y., & Zhang, H. H. (2023). Neural Network-Based Adaptive Fractional-Order Backstepping Control of Uncertain Quadrotors with Unknown Input Delays. Fractal and Fractional, 7(3), 232.*

***20.*** *Zeng, H. B., Zhai, Z. L., He, Y., Teo, K. L., & Wang, W. (2020). New insights on stability of sampled-data systems with time-delay. Applied Mathematics and Computation, 374, 125041.*

***21.*** *Zhao, Y. Z., Ma, D., & Zhang, Y. W. (2023). Adaptive asymptotic stabilization of uncertain nonstrict feedback nonlinear HOFA systems with time delays. Nonlinear Dynamics, 1-15.*