

Analysis of the Relationship between Linear Systems Theory and Artificial Intelligence in the Graduate Curriculum of Engineering

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Abstract: This study investigates the relationship between Linear Systems Theory and Artificial Intelligence within the engineering graduate curriculum. The analysis highlights their significant roles in engineering disciplines, beginning with the fundamental concepts and development trajectories of both Linear Systems Theory and Artificial Intelligence. The study addresses these two fields' complementarity and integration from theoretical research and application development perspectives. Theoretically, they share a similar mathematical foundation and play crucial roles in modeling and predicting real-world problems. From an application development standpoint, leveraging the characteristics and strengths of both can lead to more efficient and accurate implementations. The analysis, conducted from multiple angles and dimensions, concludes that the graduate curriculum in engineering should emphasize the integration of these courses in both theoretical and practical teaching. This approach will help students understand and master relevant tools and technologies, enhance their practical skills and overall competencies, and better prepare them for future developments in the engineering field.

Keywords: Linear System Theory; Artificial Intelligence; Curriculum System; Engineering Graduate Students

1. Characteristics of Linear System Theory Course

By studying the relationship between linear system theory and artificial intelligence, we can better explore the complementarity and integration between the two in-depth to promote engineering disciplines' development and innovation. As a traditional mathematical tool, linear system theory has been widely used in control, communication, image processing, and other fields. At the same time, applying artificial intelligence has brought new opportunities and challenges to studying linear system theory^[1]. Combining the two can achieve more efficient and accurate applications and provide new ideas and methods for research in related fields. In engineering graduate courses, focusing on the organic integration of linear system theory and artificial intelligence can improve students' comprehensive abilities and open up research ideas, laying the necessary theoretical foundation for their future research and practice in the engineering field^[2, 3].

The traditional linear system theory course system mainly comprises four main parts: signals and systems, continuous-time system analysis, discrete-time system analysis, and signal processing. Among them, the signal and system part discusses the essential characteristics of signals and their classification, as well as the basic concepts, properties, and classification of systems. The continuous-time system analysis part studies linear time-invariant systems and uses essential tools such as differentiation and integration to analyze the characteristics and performance of the system. The discrete-time system analysis part studies the characteristics of linear time-invariant systems under discrete time and uses tools such as difference equations for analysis. Signal processing is one of the focuses of the entire course system, involving a series of processing methods such as signal sampling, quantization, filtering, and transformation, as well as several basic digital signal processing techniques. The above four parts are closely connected and constitute the traditional linear system theory course system. This helps students understand signals and systems deeply and lays a solid foundation for subsequent learning.

2. The impact of linear system theory on artificial intelligence

2.1. The impact of the linear system theory course on artificial intelligence in theoretical research

Linear Systems Theory is a mathematical framework that explores linear systems' behavioral characteristics and properties. With the rapid advancement of Artificial Intelligence (AI) technology, new considerations have emerged regarding the application of Linear Systems Theory. In the field of AI, Linear Systems Theory has three main applications^[4]:

1) Artificial Neural Networks: Linear Systems Theory plays a significant role in the theory and application of artificial neural networks. While neural networks are inherently nonlinear systems, Linear Systems Theory can be used to investigate linear approximations of neural networks, which is valuable for developing accurate prediction and training models. It helps establish the response and stability of neural networks and analyze the relationships between inputs and outputs. Additionally, techniques from Linear Systems Theory can be applied to the control, diagnosis, and fault detection of neural networks.

2) Control System*: Linear Systems Theory is widely used in control theory. AI-driven control systems require real-time monitoring and adjustment of machine behavior to maximize performance and minimize risk. Linear systems establish the stability and dynamics of feedback control systems, enabling automatic adjustment of controllers in response to changes in system states. Control techniques based on Linear Systems Theory include Model Predictive Control, H_∞ Control, and Optimal Control.

3) Computer Science: Linear Systems Theory also significantly impacts computer science and engineering. Computer scientists use techniques from Linear Systems Theory to develop optimization algorithms and data structures, leading to faster, more accurate, and more efficient systems. For example, Linear Systems Theory plays a crucial role in applications such as image processing, signal processing, speech recognition, and machine learning.

The applications of Linear Systems Theory in AI are extensive, providing essential tools and techniques that contribute to the development.

2.2. The impact of linear system theory courses on artificial intelligence in application development

Linear Systems Theory is one of the foundational theories in the field of Artificial Intelligence (AI) with broad applications and a significant impact on the development of AI applications, specifically in the following areas^[5]:

1) Signal Processing: Linear Systems Theory plays a crucial role in signal processing, such as audio and image processing. By applying Linear Systems Theory, one can analyze how signals are transmitted through systems, reduce noise, and enhance signal processing capabilities, improving system performance and stability.

2) Control Systems: In control systems, such as those used in autonomous vehicles, Linear Systems Theory can optimize the design and adjustment of control systems, improving their precision and response speed while enhancing system performance and robustness.

3) Machine Learning: Machine learning is at the core of AI, and Linear Systems Theory is also applied in the optimization and analysis of machine learning algorithms. Applying Linear Systems Theory can optimize parameters in algorithms such as neural networks, increase prediction accuracy and performance, reduce algorithm complexity, and accelerate computational speed.

4) Speech Recognition: Speech recognition is a significant application area in AI, where Linear Systems Theory has a substantial impact. By leveraging Linear Systems Theory, one can improve the accuracy and speed of speech recognition systems while reducing noise and distortion, thereby enhancing the functionality of speech recognition.

Linear Systems Theory serves as a vital theoretical foundation in AI technologies, playing an essential role in various domains such as signal processing, control systems, machine learning, and speech recognition, and enhancing the performance and efficiency of AI applications.

3. Analysis of the relationship between linear system theory and artificial intelligence

3.1. Improving artificial intelligence application capabilities through learning linear system theory courses

Studying Linear Systems Theory can enhance the application capabilities of Artificial Intelligence (AI) in several key ways:

1) **Fundamentals of Linear Algebra:** Learning Linear Systems Theory requires a solid foundation in linear algebra, including concepts such as vector spaces, matrices, determinants, eigenvectors, and eigenvalues. These mathematical concepts are fundamental to AI, driving the development, optimization, and theoretical understanding of AI algorithms and models^[6].

2) **Fourier Transform and Frequency Domain Analysis:** Fourier Transform and frequency domain analysis are widely applied in AI fields such as image processing, sound processing, and communication. By studying Linear Systems Theory, one gains a deeper understanding of the principles and applications of these transformations and analytical methods.

3) **Control and Optimization of Systems:** The study of Linear Systems Theory involves mastering basic principles of control and optimization, such as state-space representation, feedback control, and optimal control. These principles are extensively applied in AI and are crucial in optimizing machine learning algorithms and decision-making processes.

4) **Analysis of Practical Application Cases:** Linear Systems Theory encompasses not only mathematical theory but also the analysis and practice of real-world application cases, such as control system design and signal processing applications. Learning from practical cases helps better understand AI technologies' application scenarios and implementation methods.

By studying linear systems theory, one can enhance one's AI application capabilities, deepen one's understanding of algorithmic principles and model construction, and provide a more robust mathematical foundation for advanced research and solving practical problems in the AI field.

3.2. Extension of Linear System Theory by Artificial Intelligence

The expansion of Linear Systems Theory by Artificial Intelligence is primarily concentrated in the following areas:

1) **Nonlinear Systems Theory:** With the widespread application of deep learning and neural networks in AI, Nonlinear Systems Theory has become increasingly significant in the AI field. The modeling and controlling of nonlinear systems is a complex challenge, requiring more sophisticated mathematical tools and algorithms. Deep learning algorithms, reinforcement learning algorithms, and complex dynamic analysis techniques are widely applied in studying nonlinear systems.

2) **Reinforcement Learning Theory:** Reinforcement learning, a method of improving performance through trial-and-error and feedback mechanisms, has become a popular research area in AI. The decision-making and control problems involved in reinforcement learning typically consist of nonlinear systems. Therefore, reinforcement learning is closely related to the theory of nonlinear systems and requires systems theory and optimization methods to address these challenges.

3) **Big Data Processing and Network Control:** The development of big data and cloud computing technologies has driven AI advancements while presenting new challenges for Linear Systems Theory. Big data processing demands efficient linear computations and matrix operations, while network control imposes new requirements for modeling and controlling complex nonlinear systems. Consequently, integrating AI with Linear Systems Theory is becoming increasingly tight, forming a new, efficient AI technology framework.

4) **Controller Design and Testing:** The design and testing of controllers are crucial for AI applications. In industrial control and autonomous driving areas, Linear Systems Theory and modern control techniques are often combined with deep learning algorithms to accomplish more complex control tasks. Additionally, new controller testing methods have emerged, such as chaotic testing and fluctuation testing, which are based on nonlinear dynamics theory and stochastic systems theory, addressing the shortcomings of traditional controller testing methods.

The expansion of Linear Systems Theory by AI includes various aspects such as Nonlinear Systems Theory, Reinforcement Learning Theory, Big Data Processing and Network Control, and Controller

Design and Testing. These new theories and methods enable AI to solve increasingly complex problems more efficiently. The Linear system theory and artificial intelligence in the engineering graduate course system is illustrated in Figure 1

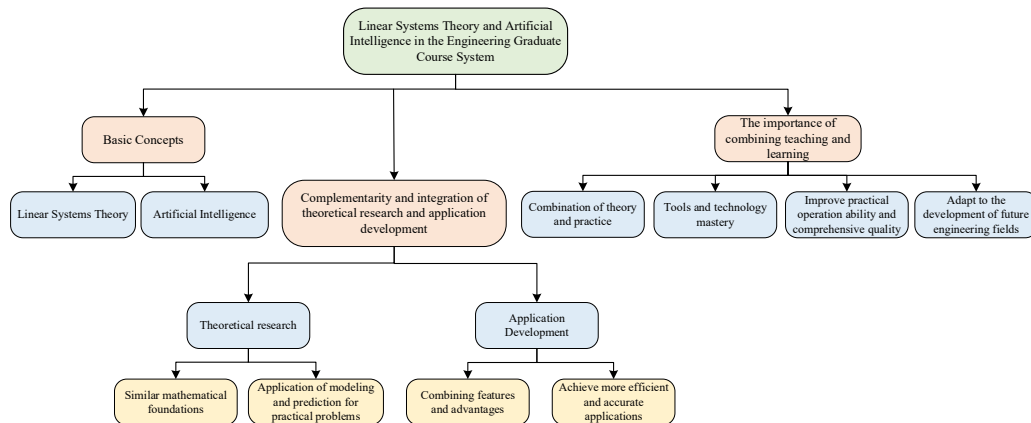


Figure 1: Linear system theory and artificial intelligence in the engineering graduate course system

3.3. Combination of Linear System Theory Course and Artificial Intelligence Training

The integration of the Linear Systems Theory course with Artificial Intelligence training can provide students with a more comprehensive AI education system, focusing on several key aspects:

1) Learning of Mathematical Foundations: Studying Linear Systems Theory requires an in-depth understanding of linear algebra and calculus. These mathematical foundations are critical in Artificial Intelligence and significantly influence the interpretation and application of machine learning, AI algorithms, and other related technologies.

2) Analysis of Practical Application Cases: The Linear Systems Theory course typically involves numerous practical cases, such as the design and optimization of control systems, signal processing, and circuit analysis. By analyzing these real-world cases, students can better understand and apply the theoretical knowledge gained in the course.

3) Learning of AI-Related Domain Knowledge: Artificial Intelligence is broad, encompassing many areas such as machine learning, image processing, and natural language processing. The knowledge acquired in the Linear Systems Theory course can be integrated with these related areas, forming a more comprehensive AI knowledge system, thereby better supporting the resolution of real-world problems.

4) Development of Students' Research Capabilities: The Linear Systems Theory course involves extensive modeling, analysis, and optimization, greatly enhancing students' research capabilities. During the course, students must use specialized software tools and algorithms for system modeling, control, and optimization. These tools and techniques are valuable not only in academic research but also in engineering practice.

Integrating the Linear Systems Theory course with AI training enhances students' mathematical foundations, practical application abilities, and research skills. Given the importance of these skills and knowledge in AI applications, this integration is highly beneficial for developing students' capabilities in Artificial Intelligence.

4. Conclusion and Outlook

The relationship between Linear Systems Theory and Artificial Intelligence within the graduate engineering curriculum is highly interconnected, with both fields complementing and enhancing each other. Linear Systems Theory, a critical component of mathematics and signal processing, aids students in understanding the characteristics and performance of systems and mastering the fundamental methods of system analysis and design. On the other hand, Artificial Intelligence, a key area in computer science and engineering, primarily focuses on issues related to machine intelligence, machine learning, and data mining. This is closely related to the application of Linear Systems Theory in signal processing and control, enhancing the efficiency and accuracy of machine intelligence. As AI technology continues to evolve and expand its applications, students must acquire comprehensive engineering skills while

mastering relevant theoretical knowledge. Therefore, the curriculum must keep pace with technological advancements by further integrating Linear Systems Theory with Artificial Intelligence, fostering students' innovative abilities and academic thinking to meet the demands of a rapidly developing technological landscape.

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