Proceedings of CONF-MLA 2025 Symposium: Intelligent Systems and Automation: AI Models, IoT, and Robotic Algorithms
DOI: 10.54254/2755-2721/2025.LD29602

The Interdisciplinary Integration of Electronic and Computer Engineering and Artificial Intelligence: Technologies, Applications, and Prospects

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Abstract. The integration of Electronic and Computer Engineering (ECE) and Artificial Intelligence (AI) has become a key force driving transformations in multiple fields, especially in industries such as healthcare, autonomous driving, and the Internet of Things (IoT). With the continuous advancements in AI technologies such as machine learning, deep learning, computer vision, and natural language processing, the combination of AI and ECE is crucial for developing intelligent systems that can enhance operational efficiency and expand functionalities. This paper aims to explore the synergistic effect between Electronic and Computer Engineering (ECE) and Artificial Intelligence (AI), with a focus on analyzing their key technologies, application domains, and future development potential. Through literature reviews, case analyses, and industry examples, this paper examines the key challenges and opportunities in the integration of AI and ECE. The research findings indicate that although significant progress has been made in the integration of the two in fields such as autonomous driving, intelligent healthcare, and the Internet of Things, many challenges still exist in hardware implementation, algorithm optimization, and data processing. Finally, this paper discusses the future prospects of the integration of ECE and AI, and emphasizes the necessity of further research and development to unleash the full potential of these technologies.

Keywords: Electronic and Computer Engineering, Artificial Intelligence, Machine Learning, Deep Learning, Autonomous Driving System

1. Introduction

The interdisciplinary integration of Electronic and Computer Engineering (ECE) and Artificial Intelligence (AI) has become an important trend in the current technology field. Electronic and Computer Engineering (ECE) mainly involves hardware design, computer architecture, embedded systems, etc., while Artificial Intelligence (AI) includes technologies such as machine learning, deep learning, computer vision, and natural language processing. The combination of these two enables intelligent systems and devices to achieve automated decision-making and efficient operation in various applications, promoting the development of multiple industries, especially in the continuous

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breakthroughs of applications in fields such as autonomous driving, intelligent healthcare, and the Internet of Things.

At present, the integration of ECE and AI has made remarkable progress in multiple fields, but there are still some challenges. For example, the perception and decision-making algorithms in autonomous driving systems require a large amount of efficient computing power, and the existing hardware architecture still needs to be improved to meet these needs. The intelligent Internet of Things (AIoT) is faced with the optimization problems of edge computing and sensor processing. Although AI algorithms have made great breakthroughs, how to deploy them efficiently to hardware platforms and achieve real-time and low-power processing is still an urgent problem to be solved. Therefore, exploring the effective integration of ECE and AI, especially in hardware architecture and algorithm optimization, is still an important direction of current research.

This paper aims to explore the integration of Electronic and Computer Engineering (ECE) and Artificial Intelligence (AI) and their applications, focusing on analyzing the integration practices of the two in fields such as the intelligent Internet of Things, autonomous driving, and medical electronics. Through the analysis of relevant cases, this paper not only summarizes the latest progress of current integration technologies but also reveals the technical challenges and bottlenecks therein. The research methods adopt literature review, case analysis, technical evaluation, etc., to conduct a comprehensive analysis of the combination of ECE and AI. The significance of this research lies in providing the academic and industrial circles with an in-depth understanding of the integration of ECE and AI and providing a reference for future technological innovation and optimization in related fields.

2. Basic theories of Electronic and Computer Engineering (ECE) and its association with AI

Electronic and Computer Engineering (ECE) covers a wide range of fields from hardware design to software systems. Its core basic theories include digital circuits, computer architecture, signal processing, etc., which are mainly used for designing and implementing intelligent systems [1]. ECE provides powerful hardware support for modern technologies, such as computer hardware, embedded systems, network communications, etc., and these technologies are widely used in various industrial and consumer electronic products. With the development of Artificial Intelligence (AI), especially in the fields of machine learning and deep learning, the integration of ECE and AI has become a hot spot of technological innovation. AI algorithms usually require a large amount of computing and data processing capabilities, while traditional hardware is often insufficient to meet these needs. The integration need of AI and ECE has promoted the design of hardware accelerators such as Graphics Processing Unit (GPU), Tensor Processing Unit (TPU), and Application Specific Integrated Circuit (ASIC) to improve computing efficiency [2].

At the same time, the development of edge computing and the Internet of Things (IoT) has further deepened the combination of AI and ECE. The intelligent devices in the Internet of Things process data in real time, which not only improves the system response speed but also reduces the cloud computing pressure. This interdisciplinary combination provides more efficient solutions for fields such as industrial automation and smart homes [3]. In addition, with the continuous optimization of AI and hardware platforms, application scenarios such as intelligent healthcare and autonomous driving have also benefited from the close combination of ECE and AI, promoting technological progress and industrial transformation in these fields [4]. This integration not only improves the hardware platform but also provides solid support for the popularization and application of artificial intelligence technologies, prompting more industries to realize intelligent transformation.

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3. Key technologies of Artificial Intelligence (AI) and hardware implementation challenges

3.1. Foundations of Machine Learning and Deep Learning

Machine Learning (ML) is one of the core technologies of artificial intelligence, which mainly learns laws from data and makes predictions or classifications. The key algorithms of machine learning include supervised learning, unsupervised learning, and reinforcement learning, etc. Deep Learning (DL) is an important branch of machine learning, which uses a multi-layer neural network model to process complex tasks and has achieved remarkable results in fields such as image processing, speech recognition, and natural language processing. The core advantage of deep learning lies in its ability to automatically extract high-level features from data and carry out multi-dimensional decision analysis.

However, deep learning models usually require a large amount of computing resources for training, especially when processing large-scale data, the amount of computation is huge. Traditional computing hardware, such as the Central Processing Unit (CPU), is difficult to meet this high-performance computing requirement, so dedicated hardware such as GPUs and TPUs is needed to accelerate the training process. These hardware can efficiently process data in parallel, significantly improving the computing efficiency of deep learning tasks. With the continuous development of hardware technology, the application fields of deep learning are also expanding, making it a key force driving the development of artificial intelligence.

3.2. Computer Vision and Natural Language Processing

Computer Vision (CV) is a technology that enables computers to "understand" image and video data and is widely used in fields such as autonomous driving, medical image analysis, and monitoring systems. AI uses deep learning models, such as Convolutional Neural Network (CNN), to extract features in images and perform tasks such as object detection, classification, and image segmentation. Although computer vision technology has made remarkable progress, in complex scenarios, especially for low-quality or occluded image data, the accuracy of the algorithm still faces certain challenges.

Natural Language Processing (NLP) is a technology that enables computers to understand, generate, and interact with humans in natural language. The core tasks of NLP include speech recognition, machine translation, sentiment analysis, etc. In recent years, deep learning models such as Transformer and BERT have made significant progress in the field of NLP, greatly improving the ability of text understanding and generation. However, NLP still faces challenges such as understanding polysemous words and context dependence. With the continuous optimization of computing power and algorithms, computer vision and natural language processing will play an important role in more practical applications.

3.3. Hardware implementation challenges of AI algorithms

AI algorithms, especially deep learning, usually require a large amount of computing power and storage resources, which poses great challenges to hardware. Traditional computing hardware, such as CPUs, cannot efficiently handle the large number of parallel computing tasks required by deep learning, so GPUs and Application Specific Integrated Circuits (ASICs) have become the mainstream hardware acceleration tools. GPUs can significantly accelerate the training process of deep learning models through parallel processing technology, while dedicated hardware such as

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TPUs further improves computing efficiency. Although these hardware have significantly improved the computing power of deep learning, when processing larger-scale data sets and complex models, the performance of the hardware is still a bottleneck. Table 1 shows the hardware requirements of AI algorithms and accelerators.

Table 1. AI algorithm hardware requirements and accelerators

Hardware Type	Applicable Tasks	Features	Examples
CPU	Basic computational tasks	General-purpose, limited processing power	General computing tasks, everyday applications
GPU	Deep learning, image processing, parallel computing	High concurrency processing power, suitable for large-scale data processing	NVIDIA Tesla series, AMD Radeon series
TPU	Deep learning, neural network computing	Optimized for AI computations, high processing efficiency	Google TPU
ASIC	Specialized computational tasks (e.g., AI model acceleration)	Dedicated hardware, highest efficiency	Bitcoin mining, AI-specific accelerators

In addition, the high energy consumption of AI and the problem of massive data storage are also major challenges in hardware design. Deep learning models usually need to process a large amount of data and complex computing tasks, which puts forward higher requirements for the energy efficiency and heat dissipation capacity of hardware. In order to meet these requirements, hardware design is developing in the direction of higher efficiency and lower power consumption. For example, emerging technologies such as neuromorphic computing and quantum computing are being explored. These technologies are expected to solve the current bottlenecks in hardware performance and energy efficiency and provide stronger support for the further development of AI.

4. Analysis of integration application practices of ECE and AI

4.1. Intelligent Internet of Things (AIoT)

The Intelligent Internet of Things (AIoT) is a technology that combines artificial intelligence with the Internet of Things and realizes the intelligent decision-making of Internet of Things devices through AI. ECE provides hardware support, especially in the design of sensors, communication modules, and edge computing devices; while AI realizes the adaptive ability of intelligent devices through data analysis and prediction. For example, in smart homes, temperature and humidity sensors use AI models to adjust the indoor environment in real time to improve comfort and energy-saving effects [5].

The application of edge computing in AIoT is particularly critical. It reduces data transmission delay and improves system response speed and processing efficiency by moving data processing from the cloud to edge devices close to the data source. For example, in industrial automation, production equipment collects data through sensors, and AI conducts real-time analysis to adjust machine operation parameters, so as to optimize the production process and reduce energy consumption.

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4.2. Autonomous driving system

The autonomous driving system is a typical application of the integration of ECE and AI. The perception module collects information about the surrounding environment through sensors (such as cameras, radar, lidar, etc.), and the AI algorithm processes these data through computer vision to realize the recognition of targets such as roads, obstacles, and traffic signs. The decision-making module decides whether to change lanes, accelerate, or brake according to the perception data. Table 2 shows the technical modules of the autonomous driving system, including the main functions of the perception, decision-making, and execution modules, as well as the corresponding AI technology support and ECE hardware support.

Table 2. Technical modules of autonomous driving system

Module	Main Function	AI Technology Support	ECE Hardware Support
Perception	Environment recognition, obstacle detection, lane keeping	Computer vision, deep learning	Cameras, radar, LiDAR, GPU
Decision	Path planning, driving decisions	Reinforcement learning, predictive modeling	High-performance computing platforms, ASICs
Execution	Control of acceleration, braking, steering	Feedback control, real-time decision making	Electronic control units (ECU), actuators

The further development of autonomous driving technology will depend on more powerful hardware platforms and more advanced AI algorithms. For example, Tesla's autonomous driving system uses deep learning and GPU acceleration technology to process perception data in real time and make decisions. The continuous progress of this technology is expected to greatly improve the safety and accuracy of autonomous driving.

4.3. Medical electronics and AI diagnosis

In the medical field, the integration of ECE and AI has greatly promoted the progress of medical image analysis and intelligent diagnosis. Medical imaging equipment captures the image data of patients through sensors, and AI analyzes these data to help doctors carry out early disease screening and diagnosis. For example, AI can identify lung nodules by analyzing Computed Tomography (CT) images, providing auxiliary diagnostic suggestions for doctors and improving the efficiency and accuracy of diagnosis.

In addition, the application of AI in personalized medicine has also begun to receive widespread attention. By analyzing the genetic information and living habits of patients, AI can help formulate personalized treatment plans. ECE provides hardware support for this process, including sensors, data collection devices, and computing platforms, while AI helps doctors make more accurate decisions in the diagnosis and treatment process.

5. Future outlook

With the continuous integration of artificial intelligence and Electronic and Computer Engineering (ECE) technologies, future research will focus on multiple directions. First, the deep integration of edge computing and the Internet of Things will promote the development of fields such as smart homes and smart cities, especially the technological breakthroughs in low latency and high reliability, which will greatly improve the intelligence level of the Internet of Things [6]. Second, the

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autonomous driving system is still a field full of challenges and potential, and how to improve the robustness, real-time performance, and safety of the autonomous driving system will become the focus of future research.

In addition, the application of AI in the medical and health field is still in a stage of rapid development, and how to achieve more efficient personalized diagnosis and treatment and remote health management has become a key direction of future research. With the development of AI technology, the integration of AI in medical equipment will make it more intelligent, thus providing more accurate diagnosis and treatment.

6. Conclusion

This paper mainly explores the interdisciplinary integration of Electronic and Computer Engineering (ECE) and Artificial Intelligence (AI), and analyzes its key technologies, application domains, and future development potential. Through the analysis of practical applications in the fields of the intelligent Internet of Things, autonomous driving, and medical electronics, this paper reveals the huge changes brought about by the integration of ECE and AI, especially the breakthroughs in edge computing, sensor processing, decision-making systems, etc. Although remarkable progress has been made at present, there are still challenges in hardware design, algorithm optimization, and data processing.

This paper still has room for in-depth discussion in terms of practical case analysis and technical details. Future research can pay more attention to interdisciplinary technical integration, collaborative optimization of hardware and software, and innovative applications of AI technology in other fields.

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