International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Application and Analysis of Artificial Intelligence in Embedded System

Nilesh Damale [1], K.T.Madrewar[2]

1Student, Deogiri Institute of Engineering and Management Studies, Chattrapati Sambhajinagar, India.

2Assistant Professor, Deogiri Institute of Engineering and Management Studies, Chattrapati Sambhajinagar, India.

ABSTRACT: The integration of Artificial Intelligence (AI) into embedded systems has emerged as a transformative paradigm, revolutionizing various domains including healthcare, automotive, smart cities, and industrial automation. This paper presents a comprehensive review of the current state-of-the-art techniques, applications, challenges, and future prospects of AI in embedded systems. Firstly, it surveys the fundamental concepts of AI, including machine learning, deep learning, and reinforcement learning, and discusses their applicability in embedded systems. Subsequently, it explores diverse applications of AI in embedded systems, such as real-time object detection, predictive maintenance, autonomous navigation, and intelligent control. Furthermore, it addresses the challenges associated with implementing AI algorithms on resource-constrained embedded platforms, including computational limitations, energy efficiency, and real-time performance constraints. The paper also highlights recent advancements in hardware acceleration techniques, software optimization strategies, and model compression methods to address these challenges. Moreover, it discusses emerging trends and future directions in the field, including the integration of edge computing, federated learning, and swarm intelligence into embedded AI systems. Finally, it concludes with insights into the potential impact of AI-enabled embedded systems on various industries and outlines avenues for future research and development. Overall, this paper provides a comprehensive overview of the current landscape and future prospects of AI in embedded systems, highlighting its potential to revolutionize the next generation of intelligent and autonomous devices.

I.INTRODUCTION

The new manufacturing model ,called smart manufacturing is characterized by numerous physical and digital technologies such as artificial intelligence,cloud computing,collaborative robots, augmented reality,additive manufacturing and Iternet of things. The convergence of AI and embedded systems heralds a paradigm shift in how devices perceive, interpret, and respond to their surroundings. Traditional embedded systems, while proficient in executing predefined tasks, often lack the adaptability and cognitive capabilities required to navigate complex and dynamic environments autonomously. However, by leveraging AI algorithms such as machine learning, deep learning, and neural networks, embedded systems can transcend their conventional limitations, enabling them to learn from data, recognize patterns, and make informed decisions in real-time.System design differs greatly from desktop programming in many ways. Standard environments with

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

practically infinite (virtual) memory and a robust debugging interface are available to desktop programmers. Instead, an embedded programmer is forced to give up such conveniences. Many various microcontrollers must be dealt with, some of which have only a few bytes of working memory and only a few kB of programme memory.Information technology has developed into a new industrial system in China as part of an effort to speed up the country's process of industrialization. An embedded system is a kind of computer system that integrates hardware and software and is capable of doing certain specialized tasks all by itself. Embedded systems may also communicate with one another. It is a comprehensive system that incorporates cutting-edge computer technology. semiconductor technology, electrical technology, and the specialized applications of a variety of different industries. The current development of embedded AI is two-way: the optimization of Al models and algorithms reduces the difficulty of deploying them on embedded devices, while hardware accelerators in embedded devices increase support for Al models and algorithms. Furthermore, hardware resources are being developed, and Al is rapidly advancing in mobile devices. For example, reference describes the deployment of neural networks on cell phones, and there are also neural networks specifically designed for mobile devices, such as MobileNet. Different from a general purpose personal computer, it is often embedded as part of a complete device. The usage of embedded systems is so widespread today, e.g. smart phones,

II. LITERATURE REVIEW:

An Embedded System (ES) interacts withthe outside world via the sensors/actuators and subjected tostrict spatial,temporal and energy constraints. Indeed, ESare heterogeneous in nature. They typically combinesoftware components(general purpose processors, DigitalSignal processors, etc.) and hardware components (ASIC for application specificintegrated circuit. FPGAfor field programmable gate arrays). Unlike a hardwareimplementation, a software

implementation has theadvantage of providing flexibility (i.e., the possibility ofreprogramming), but at the prize of satisfying performanceconstraints. An ES is called real-time if it is able to meet itstiming constraints. The principal role of ESo is not thetransformation of data as in conventional software, butrather the interaction with the physical world. It executes onmachines that are not, first and foremost, computers. In order to expedite R&D, optimise product portfolios and assist businesses in reducing costs , the authors argue in that sophisticated analytics for semiconductor design is necessary. While traditional analytics relies on data that has already been gathered and analysed in order to have a better knowledge of it, advanced analytics is a process that begins with a clear definition of what data is needed in order to make a decision. The use of advanced analytics by project teams resulted in a 10% reduction in project duration according to a study spanning 200 projects. Reviewing the literature on AI in embedded systems reveals a growing interest in leveraging machine learning and deep learning algorithms to enhance the capabilities of embedded devices. Studies highlight the potential of AI in areas such as autonomous vehicles, industrial automation, IoT devices, healthcare monitoring, and smart homes. Researchers explore various techniques to optimize AI models for resource-constrained environments, including model compression, quantization, and hardware acceleration. This provides abetter substitute to stochastic sampling algorithm that have been observed to perform poorly in evidential reasoning with extremely unlikely evidence.

III. METHODOLOGY

Methodology for doing research is a general approach to the gathering of data, the evaluation of the data and the presentation of conclusions based on the findings. A strategy for conducting a study is known as a research technique. To put it another way, research is the systematic collection and analysis of data to enhance knowledge in any field. The study's objective is to develop intellectual and practical solutions to difficulties via the application of systematic methodologies. The information gathered for this research is secondary in nature, having been taken from a variety of previously published sources.

1.Problem Definition: Clearly define the problem that the AI system will solve within the embedded system context. This could be anything from image recognition to predictive maintenance.

2.Algorithm Selection: Choose the appropriate AI algorithm or model for the task at hand. This could include machine learning algorithms such as neural networks, decision trees, or support vector machines.

3.Model Training: Train the chosen AI model using relevant data. This step is crucial for supervised learning algorithms, where the model learns from labeled data.

4.Model Optimization: Optimize the trained model to meet the constraints of the embedded system, such as memory and processing power limitations. This may involve techniques like model compression, quantization, or pruning.

IV.CONSTRUCTION

This change was necessary in order to achieve more effective software and hardware co-design. As a result of both the progression of technology and the growing importance placed on system performance. an increasing number of embedded systems are making use of specific hardware optimization and acceleration methods. This article combines a specific hardware environment with an integrated platform in order to improve the embedded environment, boost the performance of the artificial intelligence algorithm for recognition, and optimize the performance of the embedded environment overall. The bulk of embedded devices are composed of embedded computer systems and the hardware that is connected with them. A software layer, a hardware layer, a layer of system software, and an intermediate layer make up the majority of the embedded computer, which serves as the core of the system. Other layers include an intermediate layer. The majority of the time, when people talk about the software layer, they are referring to the layer of software that is used while developing embedded systems.Using a serial peripheral interface (SPI) protocol, the external data transceiver transmits data to the interface that is used for learning and recognising activities. phase-locked loop (PLL), PLL, instruction decoder, finite state machine (FSM), and controller for efficient management of Al cores are part of the Al processor. In order to keep the controller running at 64MHz and the Al cores at 16MHz, the PLL is used. Decoding a protocol for learning/recognition, the instruction decoder in the Al processor gets the dataset over the interface. The embedded microcontroller (MCU) coupled with in-house and third-party embedded software to achieve the desired result. The intelligence of embedded devices is unaffected by the lack of a general embedded system software. For example, it may be written in VC++.Because of the continual development of embedded systems, embedded technology is now widely employed across a wide variety of sectors and is essential to all aspects of

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

production as well as day-to-day life. Embedded technology has become more important in recent years. The word "embedded system" may apply to a wide range of software programs that are connected to computers. For specialized computer systems that have high requirements for performance, reliability, cost, volume, and power consumption, it is desirable to use hardware and software that can be customized. The embedded system is very relevant and is inextricably bound up with a number of different applications. It is possible to alter and personalize it to satisfy the specific needs of each application and to concentrate key efforts on those applications that have the potential to advance the development of embedded systems more effectively. The faultlessness of the function may be directly attributed to the incorporation of an MCU and software that is embedded system.

V.WORKING

A block schematic is shown in Fig 1 of the embedded artificial intelligence system. An external data transceiver serves as an interface to other systems, and an AI processor with numerous AI cores performs learning and recognition activities. The following diagram shows the working of embedded system how the signal passes to the computer and the AI response of the computer.

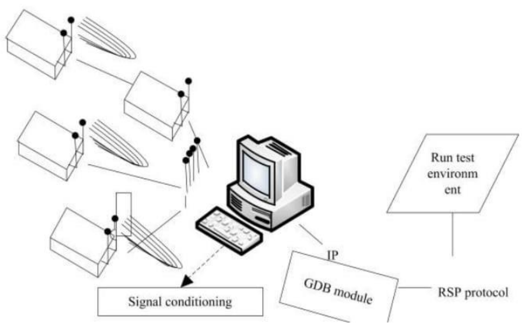

Figure.1.

Using a serial peripheral interface (SPI) protocol, the external data transceiver transmits data to the interface that is used for learning and recognising activities. phase-locked loop (PLL), PLL, instruction decoder, finite state machine (FSM), and controller for efficient management of AI cores are part of the AI processor. In order to keep the controller running at 64MHz and the AI cores at 16MHz, the PLL is used. Decoding a protocol for learning/recognition, the instruction decoder in the AI processor gets the dataset over the interface. File system, network protocol, graphics, and RTOS make up the majority of the software layer. Device drivers are independent of the hardware because of the intermediate layer, also known as driver layer software, which separates hardware from operating system software. An optimised hardware configuration is based on this.

The Outlook of Embedded Artificial Intelligence

In the Industry 4.0 environment, the digitalization process of the manufacturing industry relies on embedded intelligence technology. To achieve this, more complex and intelligent artificial intelligence algorithms and models need to be deployed to resource-constrained embedded devices. Embedded intelligence will play an important role in the digital transformation of the manufacturing industry. The following are some considerations for embedded artificial intelligence technology:

Efficient algorithms and lightweight models: In the current society, most workers need to frequently switch between different work scenarios. This results in higher requirements for device portability, including weight, volume, energy consumption, and other factors. To ensure the portability of the devices, the development of intelligent devices requires the study of more efficient algorithms and lightweight network models while maintaining model accuracy and reducing network model complexity.

Hardware acceleration methods: In addition to optimization in algorithms and models, optimization can also be achieved at the hardware level. The current research on hardware acceleration methods is limited to a single architecture of the neural network accelerator. Applying a hardware neural network accelerator to multiple platforms or using multiple hardware devices in combination may become a solution to the problem in the future.

Deployment optimization: Embedded AI deployment can be divided into post-training deployment, training on embedded devices, and part of the training task on embedded devices. Current post-training deployment has a high demand for training speed on other platforms, which can be met by improving the model training speed. The need for training on embedded devices is consistent with the first point of this subsection, requiring more efficient algorithms and lighter network models to reduce the difficulty of model training on embedded devices. For tasks completed on embedded devices, consideration of post-training models for integration is required to ensure model integrity.

Compatibility: According to reference [60], the current embedded intelligence in the industry still faces problems. For example, in legacy automation systems, some dedicated functions lack interoperability with the current automation system due to various reasons. At the same time, there is no standard method to manage the edge computing nodes and data collection. Additionally, utilizing the large amount of data generated by the edge computing and industrial cloud working together in machine learning remains an issue.

VI. ADVANTAGES

Real-time Decision Making: AI algorithms running on embedded systems can analyze data and make decisions in real-time, enabling faster response to changing conditions or events.

Efficiency: AI can optimize system performance and resource usage, leading to improved efficiency in power consumption, memory utilization, and overall system operation.

Adaptability: Embedded AI systems can adapt to varying environments or user behaviors, enhancing their ability to perform tasks accurately and effectively over time.

Autonomy: AI-powered embedded systems can operate autonomously without constant human intervention, reducing the need for manual oversight and improving system reliability.

Customization: AI algorithms can be customized and optimized for specific embedded applications, allowing for tailored solutions that meet unique requirements or constraints.

Predictive Maintenance: By analyzing data from sensors and other sources, AI can predict equipment failures or maintenance needs in advance, reducing downtime and increasing operational reliability.

Enhanced User Experience: Embedded AI can enable features such as natural language processing, gesture recognition, or personalized recommendations, enhancing the user experience in various applications.

Security: AI algorithms can help detect and mitigate security threats in embedded systems by analyzing patterns and anomalies in data traffic or system behavior.

Overall, integrating AI into embedded systems can unlock new capabilities, improve performance, and create more intelligent and responsive devices for various applications.

VII. DISADVANTAGE

One disadvantage of AI in embedded systems is the potential for increased complexity, which can lead to higher. power consumption and resource utilization, limiting the system's efficiency and scalability. Another disadvantage is the risk of increased susceptibility to security vulnerabilities, as AI algorithms may be susceptible to attacks such as adversarial examples or data poisoning, especially in resource-constrained embedded systems where implementing robust security measures can be challenging. Additionally, integrating AI into embedded systems may require specialized hardware or additional computational resources, increasing costs and potentially limiting deployment in certain applications or environments.

VIII. CONCLUSION

AI in embedded systems has significantly revolutionized various industries by enhancing the capabilities of devices, making them smarter, more efficient, and capable of autonomous decision-making. Through the integration of AI algorithms into embedded hardware, tasks that once required human intervention can now be performed autonomously and in real-time, leading to improved performance, reduced costs, and increased reliability.

One of the primary advantages of AI in embedded systems is its ability to process large volumes of data locally, without relying on external servers or internet connectivity. This enables devices to operate seamlessly in environments with limited network access or high latency, such as remote locations or industrial settings.

IX. REFERENCES

[1] Ustundag Alp, Cevikcan Emre. (2017) “Industry 4.0: managing the digital transformation” Springer book.

[2] Turing Alan. (1950) “Computing machinery and intelligence”. Mind 59: 433-460.

[3] ISO/IEC 2382:2015. Information technology — Vocabulary.

[4] Das Sumit, Dey Aritra, Pal Akash, Roy Nabamita. (2015) “Applications of Artificial Intelligence in Machine Learning: Review and Prospect” International Journal of Computer Applications 115: 31-41.

5. Di Nardo Mario; Gallo Mosè; Madonna Marianna; SantilloLiberatina C. (2015) “A conceptual model of human behaviour in socio-technical systems”. Communication in Computer and Information Science 532: 598-609.

6. Lee, E.A. (2002) Embedded Software, Advances in Computers,Zelkowitz, M. (Ed.), Vol. 56, Academic Press, London.

7. Gajski, D.D., Vahid, F., Narayan, S. and Gong, J. (1994) Specification and Design of Embedded Systems, Prentice Hall, Englewood Cliffs, NJ.