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Editorial

AICAS—PAST, PRESENT, AND FUTURE

Valeri Mladenov

Department Fundamentals of Electrical Engineering, Faculty of Automatics, Technical University of Sofia, 1000 Sofia, Bulgaria; valerim@tu-sofia.bg

1. Introduction

Artificial intelligence circuits and systems (AICAS) are electronic circuits and systems designed to solve artificial intelligence (AI) problems and perform tasks. These devices are usually implemented by analog and digital electronic elements and may be focused on specific AI problems, such as decision making, image recognition, natural language processing, and many others. AICAS are successfully applied in a broad range of areas, involving medical devices, robotics, autonomous vehicles, and smart homes. They can be also applied in cloud computing and data centers to increase the speed of AI computations. Examples of AICAS include neural networks processors (NNPs) and artificial neural networks, field-programmable gate arrays (FPGAs), digital signal processors (DSPs), and graphics processing units (GPUs), which perform parallelizable and highly effective computations. AICAS are usually designed by computer scientists and engineers with proficiency in both AI and electronics. They require a very good understanding of these areas to ensure the optimization of circuits and systems (CAS) efficiency, reliability, and performance. The purpose of this Editorial is to provide brief information on the past, current status, and future of AICAS.

2. Past of AICAS

AICAS date back to the middle of the 20th century, when scientists started to investigate the possibility of constructing machines that could carry out tasks previously performed only by humans. One of the earliest efforts to construct an electronic device capable of human-like thinking was the electronic numerical integrator and computer (ENIAC) created in 1946. The ENIAC was not specifically constructed for AI tasks, but it was the first programmable computer and was a solid base for further developments in the field. Scientists started to consider the use of artificial neural networks in the 1950s to simulate human brain operation, and this led to the development of perceptrons as simple neural networks for solving classification problems. AI research transferred to expert systems in the 1980s for solving problems in industries using knowledge-based rules. Researchers initiated the development of deep neural networks as more complex models in the 1990s, and they were able to learn from large data arrays and were applied in computer vision, speech recognition, and other fields. Significant advances in AI hardware have been achieved in the 2010s.

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3. Current State in the Field of AICAS

Nowadays, several of the significant advances in AICAS are related to NNPs, FPGAs, DSPs, GPUs, and memristors. NNPs are specialized integrated chips for creating deep neural networks (DNNs), applicable in speech and image recognition. They are based on highly parallel architectures and could execute millions of calculations per second. FPGAs are highly parallel programmable electronic schemes that could be configured and used for a broad range of computational tasks, such as real-time image processing. DSPs are specialized integrated chips for digital signal manipulation and processing and are used in AI applications such as audio processing and speech recognition. GPUs are designed for graphics rendering and are frequently used for AI computations and the training of deep neural networks. Memristor is the fourth fundamental circuit element which was predicted in the 1970s and rediscovered in HP labs in 2008. It is a novel circuit element with very good memory and switching properties, nano-size dimensions, low power consumption, and good compatibility with complementary metal oxide semiconductor (CMOS) integrated circuits. Memristors could be used for energy-efficient storing and processing information in high-density integrated chips applicable in nonvolatile memories, artificial neural networks, and neuromorphic computing circuits.

Nowadays, AICAS are applied in many fields of industry as well as in finance, healthcare, automation, and others. AI algorithms are developed and applicable in smart grids for their monitoring and control. AI is expected to become more advanced with evolving science and technologies. AICAS propose many challenges that must be considered for further developments in the field. They require significant energy consumption, and their deployment in low-power devices is one of the main challenges. It requires the advancement of energy-efficient software and hardware solutions for diminishing power consumption. AICAS use large amounts of data for efficient training and operation related to data privacy and management. They could be utilized for interpretation and understanding the reasoning of decision-making systems, related to the further development of explainable AI solutions, offering transparency and insights into decision-making procedures. For their efficient operation, AICAS require significant hardware resources related to issues such as performance limitations, scalability, and high costs. This challenge requires the efficient processing and storing of large amounts of data. Owing to the deficiency of AICAS standardization, the evaluation and comparison of different AI systems and models are challenging and require the development of standard evaluation benchmarks and metrics to enable an evaluation and comparison of AI systems and models. The interaction between humans and AI leads to some issues, such as the absence of confidence, user experience problems, and ethical concerns. The consideration of this challenge requires suitable and user-friendly AI interfaces, ethical frameworks, and regulations to guarantee that AI systems are transparent, reliable, and helpful to society. Additional research and development in AICAS are needed for addressing these issues for ensuring the efficiency and trustworthiness of these technologies.

Despite considerable advancement in the field of AICAS and electronics, there are still some open issues that scientists and researchers are working to address. AICAS frequently require large amounts of energy to perform calculations, which can constrain their scalability and practical utilization. Researchers are working on the development of energy-efficient hardware, similar to brain-like neuromorphic systems. One of the main challenges of AI is the absence of the interpretability and transparency of the considered models. This is especially problematic in AI applications for critical decision making, such as in finance and medicine. Researchers are working on the development of methods for the improvement of AI models. AICAS could be exposed to attacks that might affect the data. Owing to this, researchers are working on the creation of more secure and robust AI models, which are able to identify and defend against attacks. AI systems frequently use enormous amounts of data, and sometimes the data could be private and sensitive. An important attempt of researchers is the development of efficient methods for training AI models on sensitive data and protecting their privacy. AICAS are quite complex and require a strong integration of software and hardware for the optimization of their performance and energy effectiveness. Owing to the continuous development of AICAS, new opportunities and challenges might occur, and research engineers and scientists must continue working together to solve such problems and tasks.

AICAS are continuously developing, due to the evolvement of new research in this field. The attempts to the representation of the functioning and structure of the human brain are related to the continuous research, design, and improvements of neuromorphic computing. Neuromorphic integrated chips are based on spiking neural networks for processing information, and these networks have a high efficiency and low power consumption. Edge computing is founded on data processing on devices located on the edge of a network, instead of transferring data with a centralized cloud. This solution could diminish latency and enhance the speed and efficiency of AI applications. Quantum computing represents a new type of computation for handling complex AI problems and tasks. Quantum computers are based on quantum bits (qubits) rather than on traditional bits, and they could perform multiple calculations in a simultaneous mode that aims to make AI more transparent and interpretable by the use of explainable AI (XAI). XAI is an emerging field in AI and allows users to understand how AI systems make decisions by providing explanations and insights for the conclusions. For speeding up AI computations, hardware acceleration based on specialized hardware is applied. Examples of hardware acceleration are GPUs and FPGAs, which could perform different AI tasks and problems faster and more effectively than traditional processors. United Learning is founded on a decentralized method for AI training; the data are stored on local devices and only combined results are shared with the central server. Such solutions could enhance data privacy and decrease the data amount transmitted across a given network. The generation of new data founded on patterns in existing data is based on generative AI models. Examples of generative AI models are variational autoencoders (VAEs) and generative adversarial networks (GANs). The field of AICAS is continuously developing with new advances and discoveries.

4. Future of AICAS

An important role in the progress of modern industries and technologies is played by AICAS. They have a promising perspective and propose opportunities for future development. The development of more energy-efficient hardware is the basis for further AICAS advancements. The continuous improvements in hardware, such as the developments of neuromorphic, quantum, and edge computing, could enable AICAS to operate more effectively and to be deployed in different applications. Their increasing efficiency, productivity, and enhanced decision-making procedures determine their applicability in various industries, such as medical science, finance, transport, and many others. AI technologies are becoming increasingly accessible to a wider variety of users, owing to the continuous improvement of their user-friendly platforms and tools. With the improvement of the accessibility of AICAS, organizations and individuals will be able to leverage AI technologies and create newer AI applications. The advancements in explainable AI could improve the reliability of these systems and could make humans more confident in the results. An integration of AICAS with other advanced technologies, such as 5G networks, the Internet of Things (IoT), and blockchain, is expected, and this would improve their efficiency and applicability, making available new opportunities for modernization and progress. The continuous research on some ethical considerations related to AI, such as privacy, bias, and accountability, would enable the development of trustworthy, transparent, and beneficial-for-society AI technologies. The continuous innovations in hardware, the improved applicability in different kinds of industries, and the overall enhancements in AICAS are very promising. These perspectives highlight their potential for the advanced transformation of many industries and for enabling good opportunities for growth and innovation.

5. Conclusions

The evolution of AICAS started from the earliest AI circuits and systems, relied on Boolean algebra and simple logical gates, and has reached nowadays to the present advanced neural networks and deep learning algorithms. In the earlier stages of development, AICAS were restricted by their availability only in hardware technologies of the past. Nevertheless, with the advancements in the AI industry, more complex devices and schemes were established, as the single-layer perceptron neural network, used for simple pattern separation. AICAS are much more innovative presently, owing to the quick advancements in hardware technologies. The availability of more complex neural networks and deep learning algorithms with various applications is strongly related to progress in the creation of specialized integrated chips for AI, as FPGAs, GPUs, TPUs, and memristors.

AICAS have enabled breakthroughs in many different areas of science and industry, such as in natural language processing, computer vision, and robotics. The future development and applicability of AICAS are very promising, owing to the continuous and rapid advancements in hardware technologies. The continuous improvements in neuromorphic computing could lead to the generation of efficient and reliable AI systems, suitable for solving different complex problems and tasks. The development of quantum computing could provide a significant improvement in AI and the application of very complex and faster algorithms for solving various issues in science and industry.

AICAS have come a long way since their early days of development, and they could contribute to the future more exciting and valuable developments in technologies, sciences, and society.

Conflicts of Interest: The author declares no conflict of interest.