# Adopting Artificial Intelligence and Deep Learning Techniques in Cloud Computing for Operational Efficiency

Sandesh Achar



***Abstract*—**Artificial intelligence (AI) is being increasingly incorporated into many applications across various sectors such as health, education, security, and agriculture. Recently, there has been rapid development in cloud computing technology, resulting in AI's implementation into cloud computing to enhance and optimize the technology service rendered. The deployment of AI in cloud-based applications has brought about autonomous computing, whereby systems achieve stated results without human intervention. Despite the amount of research into autonomous computing, work incorporating AI/ML into cloud computing to enhance its performance and resource allocation remains a fundamental challenge. This paper highlights different manifestations, roles, trends, and challenges related to AI-based cloud computing models. This work reviews and highlights investigations and progress in the domain. Future directions are suggested for leveraging AI/ML in next-generation computing for emerging computing paradigms such as cloud environments. Adopting AI-based algorithms and techniques to increase operational efficiency, cost savings, automation, reducing energy consumption and solving complex cloud computing issues are the major findings outlined in this paper.

***Keywords*—**Artificial intelligence, AI, cloud computing, deep learning, machine learning, ML, internet of things, IoT.

## I. Introduction

AI is breaking ground, altering the existing paradigm of all critical aspects of innovation and computing. AI systems are capable of creating a system that can learn to imitate human behavior from previous experience without manual involvement [1]. AI was once seen as a language of extreme computer intellectuals, and a once rigid system has become flexible and implemented in different fields [2]. AI is now seen as the technology for the present and future due to its vast potential; yet it is believed that AI is still underused. The main strength of AI systems is their capability to acquire information, carefully examine it, distinguish between the examples, and make decisions. AI has helped users automate the existing and improved knowledge by eliminating the likelihood of mistakes when undertaking manual operations. Likewise, Industry 4.0 supports the creation of an intelligent factory by implementing full automation [3]. The field of information technology is headed by the latest technological innovations, such as software-defined networking (SDN), Internet of Things (IoT) technologies, and cloud computing, which has many qualities in an interconnected environment. Presented in Fig. 1 are the supporting technologies for Industry 4.0 that contribute to the output level. AI deployed alongside these technologies is at a critical phase of research and development, during which increased attention is needed to achieve sufficient maturity.


Fig. 1 Technologies Supporting Industry 4.0 [1]

Recently, there has been growing research on the description and evolution of cloud computing, and it is motivated by innovation in distributed architectures and networking. Cloud computing technology has displayed distributed systems research ever since the early start of client servers in 1958 [4]. The increasing growth of cloud computing has made it an essential tool in various fields spanning industry, academia, research centers, and governmental institutions [5]. Some features of cloud computing—such as metered and dynamic access to a joint pool of computing resources—have supported the realization and implementation of new technologies and methodological paradigm shifts to ensure the fulfilment of the demands from emerging applications such as smart systems, traffic management, security hardware, precision agriculture, healthcare systems, and scientific processes [6]. Nowadays, cloud providers are employing large-scale cloud data centers to provide comprehensive quality of service (QoS) requirements for regulators and operators. The reliability of cloud computing

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platforms was improved through the provision of a unified interface, unlike heterogeneous resources being used on IoT-based applications [7]. The operator and cloud user would sign a service-level agreement to deliver the specified budget and time based on QoS parameters.

The rest of the paper is organized as follows: Section II outlines the data flow, Section III outlines the current trends, Section IV outlines the future directions, Section V outlines the latest techniques, and Section VI outlines the roles of AI in solving cloud computing issues.

## II. Data Flow

AI algorithms have been successfully applied in various fields and have significantly outperformed the previous state-of-the-art in all these fields. Machine learning and deep learning are resource-intensive techniques that require training data to achieve a stated task with good performance. The training of AI models is carried out using high-performance tensors and GPUs. However, with the technology of AI-based cloud computing, the training and implementation of AI algorithms can be efficiently carried out in the cloud. A platform for such functionality is Machine Learning as a Service (MLaaS) [8]. MLaaS are offered as a component of cloud computing services such as natural language processing, predictive analysis, data modeling APIs, and facial recognition. The data flow in Fig. 2 involves users uploading their data and model for the training process on the cloud. With training, cloud-hosted AI algorithms can be used for decision-making purposes. The preferred AI model can be deployed in the cloud environments and follow the same data flow movement as depicted in Fig. 2.

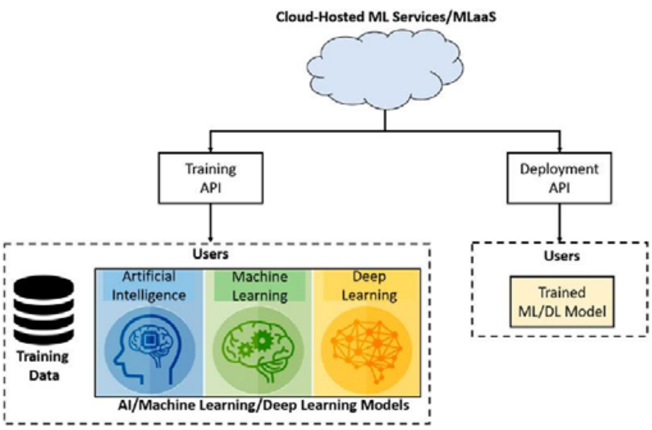


Fig. 2 Dataflow for MLaaS component of Cloud Computing [8]

## III. Current Trends

The new phase of technological evolution is highly dependent on internet facilities dominated by intelligent devices such as smart home devices, self-driving automobiles, and smart phones. The internet network is a platform for processing, hosting, and serving information that comprises applications, websites, and contents. Seamless Internet use faces significant problems such as hardware failures during network backups, storage inefficiency, and data insecurity. Therefore, the handling of remote servers and optimization of the data resources has stressed the need for and importance of cloud computing. Cloud computing technology supports instantaneous applications by offering on-demand cybernetic storage and remote access through multifaceted services such as infrastructure as a service (IaaS), software as a service (SaaS), and platform as a service (PaaS). AI is now included in cloud/edge computing to program complex repetitive tasks such as data analysis without human involvement. Yet over time, security and latency issues have been identified in the AI-enabled cloud. An AI-based cloud computing environment helps manage data repositories and enhances automation and data flow. This platform also provides flexibility and quickness in rationalizing operations. One AI model incorporated by the most popular platforms is the text-to-speech algorithm [9], and additional popular cloud AI solution providers are reviewed in the following subsection.

Incorporating AI in the cloud can enhance the cloud's efficiency, digital transformation, and overall performance [10]. An AI-enabled cloud computing environment is essential to enable organizations to become more strategic, insight-driven, and efficient while offering more significant cost savings, agility, and flexibility [11]. The two technologies can be combined in various ways to provide an excellent platform for improving efficiency. Applications and data hosted on the cloud make business enterprises more adaptable and responsive in their dealings while reducing production costs [12]; thus, businesses will benefit tremendously from the mix of these two unique technologies. Furthermore, the cloud has been likened to a video game that emits a considerable amount of operating telemetry and data, just like the tech used in self-driving cars [13]. Therefore, AI-based cloud computing is essentially AI Ops that employ an algorithm to make sense of all available data rather than depending on humans [14], [15]. Nastic et al. [16] reported that incorporating AI and cloud computing can help businesses move closer to their customers while increasing operational efficiency. Some advantages of deploying AI in the cloud include cost savings, automation, and improved data management.

### A. Cost Savings

Cloud computing only charges businesses for the resources they utilize. Robertson et al. [17] reported that significant money is saved when using cloud computing compared to the conventional infrastructure cost of designing and maintaining massive data banks and centers. The saved money can be used to develop more strategic AI tools and accelerators that can be used to generate more revenue and make more cash available for the company, thereby leading to enhanced working quality and lower expenses [18].

### B. Automation

The combination of cloud and AI has eliminated the last stumbling block in the possible deployment of smart automation systems in business environments [19]. One of the main advantages of this technology is predictiveness; the AI-based cloud platform has improved the prediction process in automation by using the historical data and other patterns within the data to deliver valuable insights [20]. The deployment of AI and cloud computing platforms can help businesses move from semi-organized to unstructured documents cognitively automated, pushing the limits of active infrastructure management and ensuring little impact and downtime [21]. As a result, the customer experience is enhanced and the cost of doing business is lowered.

### *C. Improved Data Management*

Data are the new oil; it is imperative in today's data-driven world and better methods of handling data are required. The major problem is an enterprise's ability to track data [22]. Cloud-based AI applications and tools can update, recognize, index, and offer valuable insights to clients. AI algorithms can detect and track fraudulent activities and spot strange system trends [23]. Nowadays, financial institutions rely heavily on AI-based technology to ensure a competitive edge and security in present-day high-risk environments.

## IV. Future Directions

Gill et al. [24] identified unresolved problems and clear research paths that require wide-ranging investigation to ensure efficient implementation and optimum performance of AI-based cloud computing.

1. QoS and cloud service reliability must be sustained using advanced deep or machine learning algorithms.
2. AI-based autonomic computing is increasingly becoming an essential platform for the IoT and other systematic applications.
3. To reduce energy consumption and boost reliability, network visualization must be made available at a realistic cost in a software-defined, network-based cloud computing environment that employs AI models.
4. Resources scheduling in cloud computing can be enhanced by incorporating AI-enabled algorithms.
5. Cloud-based big data analysis tools deployed with AI functionality can identify trends in customer behavior and provide better understanding and decisions for the customer. This process can be implemented seamlessly through efficiently processing scaling choices appropriately using AI algorithms.

## V. Latest Techniques

Due to the growing development of information technology in cloud computing, several advanced technologies leveraging AI can be integrated into cloud computing to improve its applicability to various fields. Some of these latest technologies are highlighted the following subsections.

### 1. AI for Cloud-Assisted Smart Factory (CaSF)

The paradigm shift in the production industry is apparent in near-daily advances in the manufacturing environment. Lately, it has been moving from conventional production patterns to intelligent production settings [25]. Presently, the market demands are overloaded, and conventional single and mass production industries find it challenging to meet these growing demands in terms of different varieties, personalized customization, and small batches [26]. Therefore, transitioning from a conventional manufacturing platform to an intelligent production model is a pressing issue that must be addressed. Wan et al. [27] proposed an intelligent manufacturing platform capable of creating a smart factory based on cyber–physical systems (CPSs). CPSs require technical support, and some of the support work can be AI automated [28]. Smart factories based on cloud computing have many low-cost computing and storage resources that can aid the dynamic reconstruction and augmented distribution and offer dependable support for the application of big industrial data [29]. The deployment of AI technologies in smart factories has brought about significant changes by including smart devices integrated with AI algorithms, collaborative mechanisms with autonomous decision-making and reasoning capabilities that exhibit more appropriate dynamic behaviors, and a data processing model based on the advanced Al techniques. Therefore, AI technologies have injected modern automation into intelligent factories. Fig. 3 presents a schematic of the Cloud-Assisted Smart Factory Architecture, and there are four distinct layers—the application layer, smart device layer, cloud layer, and network layer. Incorporating AI in intelligent factories enhances the manufacturing system performance in terms of analysis, perception, data processing, and communication [30].

### 2. Edge–Cloud Computing and AI in the Internet of Medical Things

The Internet of Medical Things (IoMT) is another concentrated embodiment of IoT technology in the healthcare system. It is fundamental to the digital medical revolution. Shit et al. [32] defined IoMT as the multifaceted IoT technologies—such as positioning technology, radio frequency identification (RFID) technology, and sensor technology—that are applied to the medical field in combination with mobile terminals, network communication, and other devices to advance the patient–medical personnel/institution relationship and to achieve the automation, intelligence, and digitalization of the healthcare system. IoMT serves all facets of the healthcare system, such as vital signs, medical drugs, identity recognition, remote monitoring, and equipment monitoring. Incorporating IoT in the medical field helps to achieve intelligence in medical information management [33]. Presented in Fig. 4 is the architecture of the IoMT. This structure has three distinct layers: the network layer, the application layer, and the perceptual layer. The application layer handles the medical information application and medical information decision-making application.

The conventional IoMT platform finds it challenging to connect many different medical institutions and information systems, resulting in the isolation of the medical service information island. Incorporating cloud computing in IoMT has recently led to high dependability, scalability, and secure sharing of vital information; it has enhanced the medical field reformation. The architecture of medical cloud IoT is shown in Fig. 5. IoMT architecture is divided into three main layers: the user layer, medical service layer, and service management layer. Applying AI algorithms to medical IoT has brought about faster, safer, more efficient, and automated medical processes.

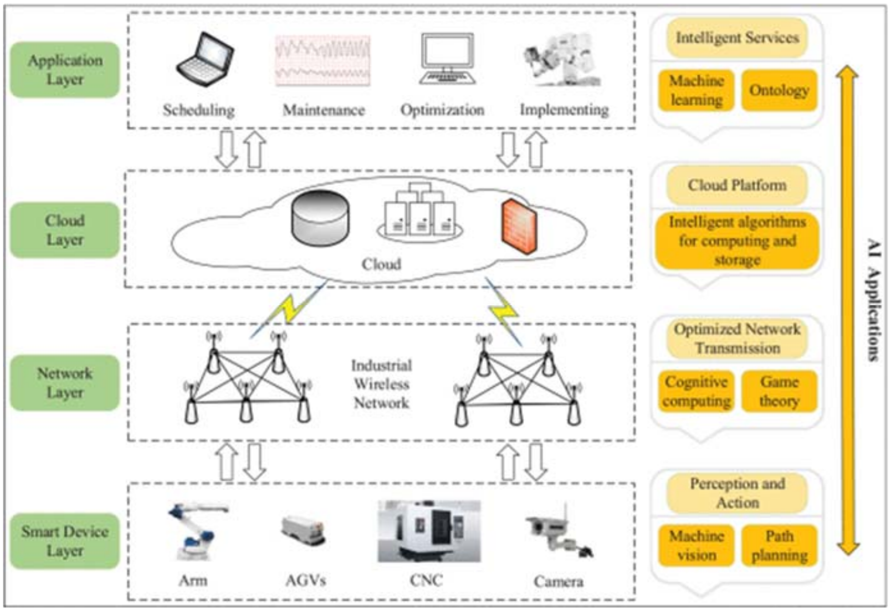


Fig. 3 Cloud-Assisted Smart Factory Architecture (CaSF) [31]

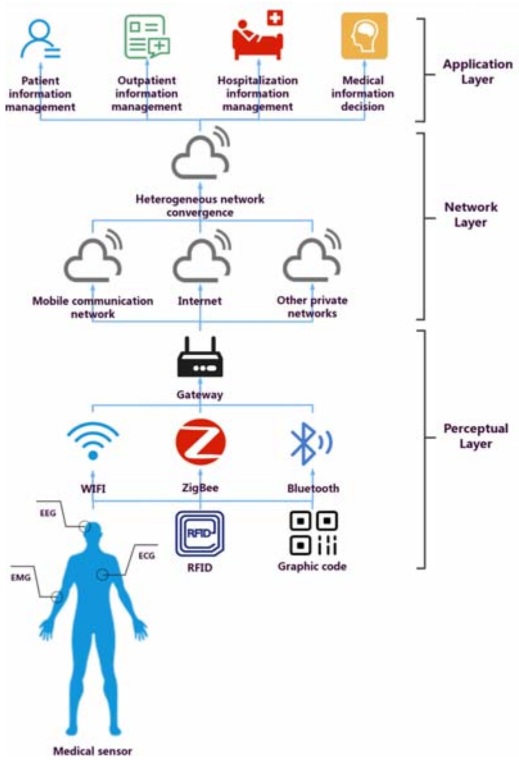


Fig. 4 Internet of Medical Things (IoMT) Architecture [34]

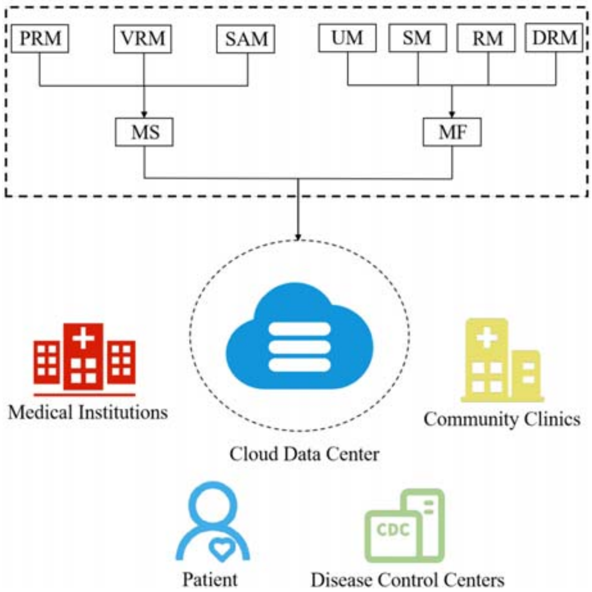


Fig. 5 The Structure of the Medical Cloud IoT [34]

## VI. Roles of AI in Solving Cloud Computing Issues

The incorporation of AI into cloud computing and thus making it accessible to users can be achieved by attaching the cloud infrastructure with AI applications through nonstop implementation, phased deployments, and continuous delivery. Hummer et al. [35] proposed a model optimizer implemented with AI for cloud-based development management to reduce and manage placement risks. Over time, the resource management issue has been left unaddressed. Software architects are striving to develop a reliable and scalable cloud-assisted smart factory that relates different AI technologies and is supported by the capabilities offered by AI algorithms.

Implementing AI in cloud computing aims at a self-managing cloud service with efficient productivity. We have anticipated that when AI develops, more complex, public, and private clouds may rely heavily on AI platforms to control, track, monitor, and self-heal autonomously when an issue arises. Table I presents some of the major issues in cloud computing to guarantee dependability and support scalability, along with the role of AI in providing answers.

TABLE I
ROLES OF AI IN SOLVING CLOUD COMPUTING ISSUES

| Major Issues in Cloud Computing | Roles of AI in Addressing these Issues |
|---|---|
| Fault Management and Flexibility | Tasks can be mapped to virtual machines using AI algorithms such as evolutionary computing, Neural Networks, and Fuzzy Systems. Machine learning with these algorithms can be used to predict faults. |
| Load Balancing | Load imbalance can be tracked and detected using Neural Networks; it can be used to map virtual machines and reliability problems. |
| Infrastructure Optimization | Machine learning algorithms can be employed for multi-objective optimization. Also, operating status can be classified using fuzzy systems and Neural Networks. |
| Cloud Service Pricing | Evolutionary computing can be used for the optimization of multi-objectives. Machine and Deep learning algorithms can be used to predict market price drift and user demand; also, these algorithms can be used to map demand and cost for a price. |

## VII. CONCLUSION

The evolution of technology has transformed users' day-to-day activities, ranging from connecting globally through communication platforms and social media applications to prompt access to critical and routine information, thereby making the way of living more accessible. To further improve user experience and satisfaction, cloud computing represents a cost-effective data and application storage method. Cloud computing offers extra benefits when compared with conventional computing platforms. Companies are increasingly adopting cloud methods to improve the flexibility of their information technology resources and reduce cost IT costs. However, cloud computing technology can be further improved with AI technology, inspired by the working principle of the human brain. Several benefits of incorporating AI into cloud computing were highlighted, such as improved cloud efficiency, cost savings, improved data management, digital transformation, and overall system performance. Furthermore, AI is projected to solve salient cloud computing issues such as load balancing, infrastructure optimization, cloud service pricing, management and flexibility. Current applications of AI-based cloud computing systems have recorded tremendous success. Future directions were suggested for leveraging AI/ML in next-generation cloud computing and other emerging computing paradigms to improve the existing technology further.

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