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Precision Farming Using Edge Analytics and Edge Intelligence: Literature Review

Parul Saxena[1], Rakesh Kumar[2]

Research Scholar, Department of Computer Science & Engineering, Rabindranath Tagore University, Bhopal, India[1]

Associate Professor, Department of Computer Science & Engineering, Rabindranath Tagore University, Bhopal, India[2]

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ABSTRACT

Precision Farming integrates advanced technologies to enhance crop production while maintaining environmental sustainability. By leveraging the Internet of Things (IoT), sensors are strategically deployed in fields to monitor agricultural parameters in real time. The integration of Edge Analytics further minimizes latency by enabling faster data processing at the edge, while Edge Intelligence enhances systems with decision-making capabilities. This study compares various computational models and technological approaches within Precision Farming, highlighting their effectiveness in achieving optimized crop growth. The comparative analysis also synthesizes insights from existing literature, offering valuable perspectives for researchers and practitioners in sustainable agriculture. Conclusively, Edge Intelligence and Edge Analytics hold significant potential for advancing precision agriculture, their integration in this domain has received relatively limited research attention.

I. INTRODUCTION

In today's world, where variety is highly valued whether in commodities or food little attention is given to understanding how a single grain is cultivated. To truly appreciate the importance of food, it is essential to gain awareness of the agricultural methods employed in the fields. At its core, agriculture may be defined as the art and science of cultivating soil, growing crops, and raising livestock. It encompasses the preparation of plant and animal products for human use and their distribution to markets [1]. Agriculture represents a vast domain that includes production, research, and development, while farming serves as the practical implementation of these agricultural activities. More specifically, it involves cultivating the soil to grow crops and rearing animals to provide food, fiber, wool, and other essential products. Precision agriculture, also referred to as smart or precision farming, is a modern agricultural approach that integrates information and communication technologies (ICT), sensing devices, data analytics, and intelligent decision-support tools to monitor, analyze, and manage spatial and temporal variations within fields. The central objective of this practice is to apply resources—such as water, fertilizers, and pesticides—in a site-specific and timely manner, ensuring higher crop yields, improved sustainability, and more efficient utilization of agricultural inputs.

Edge analytics is a data processing paradigm in which analytical computations are performed directly at or near the location where data is generated, rather than relying solely on centralized cloud or remote servers. By enabling real-time filtering, aggregation, and interpretation of raw data at the network's edge, this approach reduces latency, minimizes bandwidth usage, and allows for faster decision-making in time-critical applications such as precision agriculture, healthcare, and smart cities.

Edge intelligence refers to the convergence of artificial intelligence (AI) and edge computing, where computational models and learning algorithms are deployed directly on edge devices or near the source of data generation. This approach enables real-time data processing, adaptive decision-making, and autonomous operations with reduced dependency on cloud infrastructure, thereby enhancing efficiency, privacy, and responsiveness in applications such as precision agriculture, healthcare, and industrial automation.

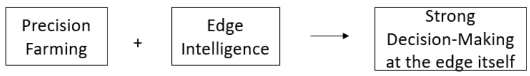

Figure 1: A conceptual diagram of Edge Intelligence integration with Precision Farming.

In Figure 1, the integration of precision farming is shown. It shows that if the idea of edge intelligence is used with Precision Farming, the result will be strong decisions that can be made at the edge itself based on the computations performed by Edge Analytics.

As IoT is finding its place everywhere, Agriculture should not be deprived of it. The technologies nowadays are capable of boosting the quality and volume of the crop. Every crop needs certain things which are common but varies in timing, quantity, etc. like irrigation, fertilization, soil nutrients, temperature requirements, pest control. For ensuring the right growth, the crop must be facilitated with exact pre-requisites and supply of various resources on time.

The precision farming states the use of all the resources and requisites in farming to be used in proper proportion i.e, using right practices at right time at right place and in right quantity. All the stages used in precision farming use adequate number of resources for the optimized quality and growth of the crop. Here eight stages are used to produce a crop. First is Crop selection, which includes the selection of a suitable crop according to the environment, water availability, climate of the area etc. Second is Making the land suitable. The land must be cleared of any rocks or unfertile pebbles in the way of the farming. Large tractors equipped with plows, harrows, or disks are often used to break up soil, turn over turf, and remove small shrubs or vegetation. Seed selection is the next step. The seed selection must be ensured so that they are of best quality. As good as the quality of the seeds the good will be the quality of the crops.

The seed sowing must be done at the perfect time. For many crops, spring is the ideal time to sow seeds, as the weather starts to warm up. In temperate climates, after the last frost date, seeds are typically sown outdoors. This ensures that the risk of frost, which could damage young plants, has passed. In warmer climates, some seeds can be sown earlier in the season.

The irrigation should be on proper timings. The selection of fertilizers must be like that there is no harm to the soil. Its capacity to produce crops must not be hindered by the chemicals used. Also, there must be precise quantity of everything that is used for nourishing the crops. This process is natural. But to maximize the growth of the crop, a proper framework is needed to automate the things according to the environmental readings.The objective of this review is to compare some state-of-the-art models which serves as good models in the field of precision farming.

II. LITERATURE REVIEW

Singh et al., presented a design of a multidisciplinary agriculture solution model for Precision Agriculture AgriFusion combining emerging technologies like Machine Learning (ML) and Artificial Intelligence (AI), nanotechnology and Software Defined Networks (SDN), edge computing, blockchain, nanotechnology, remote sensing, energy harvesting, WSN, cloud and edge/fog-based computing [1]. Revathy et al., proposed Blockchain based Producer-Consumer Model (BPCM) which allows farmer to sell their goods directly to the consumers by preventing the interagents to gain profit over farmers using smart contracts [2]. Ferrag et al., describes four-tier green IoT-based agriculture architecture and focus in on smart agriculture. Secure and privacy-preserving technologies for IoT applications are also described and it is shown that how these technologies can be used towards green IoT-based agriculture [3].

Radoglou-Grammatikis et al., provide a survey on 20 applications about the potential use of Unmanned Aerial Vehicles in Precision Agriculture [4]. Dimosthenis et al., reviewed recent applications of Unmanned Aerial Vehicles for Precision Agriculture. The most common applications, the types of UAVs exploited and the data acquisition methods and technologies are discussed, disclosing some merits and demerits [5].

Angin et al., proposes a low-cost farmland digital twin framework named as AgriLoRa for smart agriculture. It comprises wireless sensor network being set up in the farmland and there are cloud servers, on which algorithms run and find out the defected plants, weeds, and plant nutrient deficiencies [6]. Sishodia et al., analysed the studies that have been done between 2015 and 2020 about remote sensing systems, techniques, and vegetation indices [7]. Merz et al., summarizes agriculture-related UAS applications. A FarCloud drone Task is explained with input, scope and output. This project from Europe is being discussed [8]. Bhat et al., create awareness about big data applications. Use of AI and Big Data as information and Communication Technology in the field of agriculture is discussed [9]. Caruso et al., presents how wireless sensor networks are placed in the ground. It has been analysed that at what spaces the sensors must be fitted and at what height drones need to fly on the crops so that it can catch the data on the sensors [10]. Remote sensing techniques like drones, satellite and aircraft are discussed [11]. Gardezi et al., conducted a survey on certain locations amongst some farmers and received suggestions and told their deep concerns about technology [12]. The paper presents the look of LoRa based intelligent irrigation system based on soil and weather conditions [13]. Anand et al., proposes a deep learning framework AgriSegNet for automatic detection of farmland anomalies like standing water, weed clusters, obstructs the farming practices, that causes improper use of farm space [14]. Akhter et al., projected the prediction model for Apple sickness within the apple orchards of geographic, region depression victimisation knowledge analytics and Machine learning in IoT system. This paper describes web of things, wireless sensing element networks, knowledge analytics and machine learning in agriculture [15].

Cicioğlu et al., planned IoT-based sensible Agriculture observation model. These device nodes are created to sense these properties like Temperature, Rain Wind, Acoustic, pH levels of the cornfields, Humidity, Location and Chemical for sensible agriculture applications [16]. Here the summary of rising technologies for soil assessment and waste matter observation with relevancy significant metal, employed in preciseness agriculture [17]. In the proposed framework, the secure data transfer in the cloud is achieved using blockchain technology. Further, energy efficient data transfer is attained by means of Improved LEACH algorithm [18].

Amin et al., analyzes the existing and evolving edge computing architectures and techniques for smart healthcare and identification of vital signs exploitation progressive deep learning techniques. This study conjointly presents a comprehensive analysis of the employment of newest artificial intelligence-based classification and prediction techniques utilized for edge intelligence [19].

Plastiras et al., expressed that for a wide range of emerging applications edge intelligence is a necessary evolutionary need, and thus a summary of the challenges and opportunities that arise from this need [20]. Liu et al., presented a comprehensive survey on the latest developments of precision agriculture with UAV RS and edge intelligence [21]. Shadrin et al., presented an embedded sensing system enriched with the AI, ensuring the continuous analysis and in situ prediction of the growth dynamics of plant leaves [22]. Patrício et al., highlight computer vision solutions combined with artificial intelligence algorithms that achieved important results in the detection of patterns in images considering 5 main types of grains [23]. Li et al., first introduce deep learning for IoTs into the edge computing environment. Researchers also design a novel offloading strategy to optimize the performance of IoT deep learning applications with edge computing [24]. The key contributions of the paper are as follows-a clear explanation to distinguish between the three concepts of edge technology: edge devices, edge computing, and edge analytics, along with their issues [25]. This paper discusses the implementation of edge analytics to solve many problems and applications in various areas such as retail, agriculture, industry, and healthcare. It details the need for edge computing in real-time systems and IoT environments [26]. Researchers explores the convergence of edge computing and AI, discussing applications and benefits. This article highlights the architectural aspects of edge intelligence and its implications for IoT applications. The role of edge intelligence in enhancing IoT systems is discussed. This comprehensive survey covers various architectures and technologies for implementing edge intelligence. Another survey presents an in-depth review of edge AI technologies, challenges, and future directions [27-31].

Bhargava et al., explore the application of edge analytics to enhance data collection processes in precision dairy farming. The authors discuss how edge computing allows for data to be processed closer to where it is generated—in this case, within dairy farms themselves—enabling faster and more efficient data processing [32].

III. COMPARISON

Table 1 explores the comparison of some models related to this work. There are 32 research works are compared with respect to the technologies used in the work including, frameworks, review papers, models. The technologies considered here are Artificial Intelligence, edge intelligence, big data, Machine learning, Deep Learning, Fedrated Learning, Wireless sensor networks, edge computing, Blockchain and securirty methods used, Remote sensing, Cloud or fog computing, IoT architecture or IoT devices like UAV (Unmanned Aerial Vehicle) , Data Analytics, Precision Agriculture. The research work

TABLE 1: COMPARISON OF MODELS

Technologies (→)												
Ref No.	**Author's Name**	**AI/ EI**	**Big Data**	**ML/DL/FL**	**WSN**	**Edge Computing**	**Blockchain/Security**	**Remote sensing**	**Cloud/Fog**	**Iot Architecture**	**Data Analytics**	**Precision Farming**
[1]	Singh et al.	√		√	√	√	√	√	√	√		√
[2]	Revathy et al.						√					√
[3]	Ferrag et al.						√					√
[4]	Radoglou-Grammatikis et al.				√					√		√
[5]	Tsouros et al.									√		√
[6]	Angin et al.				√				√	√		√
[7]	Sishodia et al.		√					√				√
[8]	Merz et al.	√	√							√		√
[9]	Bhat et al.	√	√	√							√	√
[10]	Caruso et al.				√					√		√
[11]	Rejeb et al.			√				√		√		√
[12]	Gardezi et al.		√	√								√

[13]	Singh et al.			√						√		√
[14]	Anand et al.	√		√				√		√		√
[15]	Akhter et al.			√	√					√	√	√
[16]	Cicio˘glu et al.				√					√		√
[17]	Akhtar et al.				√	√				√		√
[18]	Anand et al.				√		√			√		√
[19]	Amin et al.	√				√			√	√		
[20]	Plastiras et al.	√		√								
[21]	Liu et al.	√		√		√		√	√	√		√
[22]	Shadrin et al.	√										√
[23]	Patrício et al.	√										√
[24]	Li et al.			√		√				√		
[25]	Nayak et la.	√	√	√		√					√	
[26]	Satyanarayanan					√			√	√		
[27]	Deng et al.	√		√		√						
[28]	Shi et al.	√		√								
[29]	Sahni et al.					√				√		
[30]	Xu et L.	√				√						
[32]	Bhargava et al.				√							
[33]	Khattab et al.				√				√	√		√

IV. CONCLUSION AND FUTURE SCOPE

The existing body of literature highlights significant advancements in the application of various technologies within the domain of precision farming; however, a substantial portion of this research remains focused primarily on review-based studies. Notably, the integration of edge analytics and edge intelligence in precision agriculture is still underexplored, particularly in scenarios where data should ideally be pre-processed and refined before the application of intelligence at the edge.

Industry efforts are increasingly directed toward deploying artificial intelligence at the edge, as this technological convergence offers vast opportunities by enabling computational power and decision-making capabilities directly at the point of data generation. This review seeks to emphasize the potential outcomes of combining these two technologies, with the objective of providing practical and immediate benefits to farmers.

Future research can be extended to crop-specific applications, tailoring frameworks to address distinct requirements such as optimal temperature conditions and precise fertilizer dosages at different growth stages. Such targeted approaches can enhance both the efficiency and sustainability of precision farming practices.

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