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A Study of the Application Domain of a Large Language Models in the Agricultural Sector

Saikat Banerjee[1], Soumitra Das[2], and Abhoy Chand Mondal[3]

[1] State Aided College Teacher, Department of Computer Applications, Vivekananda Mahavidyalaya, Haripal, Hooghly, West Bengal, India
[2] Department of Computer Science, University of Burdwan, Golapbag, West Bengal, India
[3] Professor & Head, Department of Computer Science, University of Burdwan, Golapbag, West Bengal, India

Correspondence should be addressed to Saikat Banerjee; saikat.banerjee56@gmail.com

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ABSTRACT- Given the expanding global population and the increasing need for food, employing effective agricultural techniques to enhance productivity on finite land resources is imperative. Artificial Intelligence is increasingly widespread in agriculture, and Artificial Intelligence driven solutions enhance the existing farming system. Agricultural productivity relies on soil nutrient composition, moisture levels, crop rotation, precipitation, temperature, etc. Artificial intelligence-based products can utilize these characteristics to monitor agrarian productivity. Industries are increasingly adopting Artificial Intelligence technologies to enhance and streamline agricultural activities across the whole food supply chain. Agricultural applications and solutions utilizing artificial intelligence have been developed to support farmers in precise and controlled farming practices. These applications provide accurate guidance on water management, changing crops, timely harvesting, crop selection, optimal planting, pest control, and nutrition management. Artificial Intelligence enabled systems utilize data such as precipitation, wind speed, temperature, and sun radiation, together with images captured by satellites and drones, to compute weather forecasts, monitor the sustainability of agriculture, and evaluate farms for the existence of infectious illnesses, pests, or undernourished plants. A large language model is a form of artificial intelligence that employs deep learning techniques to analyse and comprehend natural language. It is trained on extensive text datasets to discern statistical correlations between words and phrases. Subsequently, it may produce text, translate material, and execute other natural language processing operations. This research demonstrates how large language models emphasize the agricultural industry.

KEYWORDS- Artificial Intelligence (AI), Large Language Model, Agriculture, Natural Language Processing (NLP), Machine Learning

I. INTRODUCTION

Among the difficulties Indian agriculture faces are scattered landholdings, climate change, low productivity, soil degradation, water scarcity, pest and disease management, and supply chain inefficiencies. Precision farming, crop monitoring and disease identification, intelligent irrigation systems, predictive analytics for weather and crop yields, supply chain optimization, automation in agriculture, soil health monitoring, market insights and price forecasting, and artificial intelligence (AI) can help address these challenges.[9] Remote sensing technologies and artificial intelligence are used in principal farming systems to maximize farming operations according to soil conditions, crop demand, and climate patterns.[10] Early detection of agricultural illnesses made possible by artificial intelligence models helps to lower the demand for all-around pesticide use and improve crop conditions. Intelligent irrigation systems reduce water waste and improve water-use efficiency by monitoring soil moisture, weather forecasts, and crop needs. Using vast datasets, predictive analytics for weather and crop yields generate models that project future weather patterns and crop output.[11] AI-powered systems can enhance supply chain effectiveness through demand prediction, logistical optimization, and post-harvest loss reduction. Automation in agricultural operations can save labor costs and increase operational effectiveness by using robotics and drones. Analyzing soil data helps one better monitor soil health by revealing information on organic matter concentration, pH levels, and nutrient shortages. Price projections and market analysis can also enable farmers to better schedule their marketing campaigns and crop cycles. When we consider the potential of artificial intelligence, we see a future where the most pressing issues in Indian agriculture can be effectively addressed.[12] This transformative technology holds the promise of significantly improving food security, sustainability, and the livelihoods of our farmers.[13]

Through creative ideas to improve sustainability, efficiency, and production, artificial intelligence (AI) is transforming agriculture. Among the important uses are precision farming, crop monitoring, disease detection, soil and weather analysis, robotics and automation, yield prediction, pest and weed management, supply chain optimization, and cattle monitoring. Through extensive data analysis, artificial intelligence systems forecast ideal planting, watering, and harvesting periods, optimizing yields and minimizing resource waste. They also limit environmental effects, maximize fertilizers, irrigation, and pesticide use, help identify diseases, nutrient shortages, and pests, and optimize their utilization. While AI models forecast future harvests, properly manage resources, and lower food waste, AI-driven robots, and automated machinery are employed for chores, including planting, weeding, harvesting, and sorting crops. [11-14]

Artificial intelligence (AI) is the creation of computer systems that can do tasks usually requiring human ability, such as reasoning, problem-solving, and decision-making. Among the several technologies covered by artificial intelligence (AI) are robotics, computer vision, natural language processing (NLP), deep learning (DL), and machine learning (ML). Among the several varieties of artificial intelligence are narrow artificial intelligence, which specializes in particular tasks; general artificial intelligence, which can understand and execute any intellectual work; and superintelligence, which exceeds human intelligence in all spheres. While deep learning uses neural networks replicating human brain structure, ML trains systems learning from data. With chatbots, translating tools, and voice recognition systems applications, NLP helps robots understand, interpret, and respond to human language. While computer vision lets machines analyze visual data, artificial intelligence-driven robotics employs machines to accomplish tasks autonomously or semi-autonomically.[12-15]

Especially in natural language processing (NLP), computer vision, and other fields, large learning modules (LLMs) have become rather important in artificial intelligence. Their main goals are to scale machine learning models with many parameters using significant computational resources, enabling the model to understand and produce high-quality replies or predictions in challenging tasks. The research environment of LLMs—especially their structures, training approaches, and applications is investigated in this literature review.

II. LITERATURE REVIEW

Vaswani et al. [1] introduced the Transformer model, a groundbreaking innovation that revolutionized sequence modeling. By replacing recurrent structures with multi-head attention and employing self-attention mechanisms, it significantly improved parallelization efficiency during training and reduced training duration, opening up new possibilities in AI research.

Brown et al. [2] presented GPT-3 (Generative Pre-trained Transformer 3), a language model that has set a new benchmark in the field. With its 175 billion parameters, GPT-3 has demonstrated an unparalleled proficiency in few-shot learning, generating high-quality text with minimal task-specific input, a feat that was previously considered challenging.

Shoeybi et al. [3] examined the Megatron-LM, a framework developed for the practical training substantial transformer models. It implemented model parallelism, allocating the model across GPUs to mitigate memory limitations.

Radford et al. [4] highlighted the significance of transfer learning in GPT-2. The model demonstrated exceptional performance across several applications by pre-training on extensive text corpora and fine-tuning downstream tasks without requiring task-specific training data.

Strubell et al. [5] emphasized the ecological expenses linked to extensive NLP models. They contended that the training and optimization of these models need substantial energy resources, necessitating more sustainable techniques in AI research.

Thakkar et al. [6] analyzed the ethical ramifications and possible biases inherent in LLMs. These models frequently adopt biases inherent in the training data, resulting in issues of justice and accountability.

Ramesh et al. [7] created DALL·E, an image-generating model with a GPT-3-like architecture. It produces high-quality images from textual descriptions, showcasing the adaptability of LLMs across several modalities.

Devlin et al. [8] presented BERT (Bidirectional Encoder Representations from Transformers), which emerged as a fundamental model for several NLP tasks, including question answering, named entity recognition, and sentiment analysis.

III. APPLICATION AREA IN AGRICULTURE

Many challenges facing India's agricultural sector impact farmers' means of subsistence, resilience, and efficiency. Among the main problems are:

- ***Water Scarcity and Irrigation Limitations:*** Indian agriculture is quite vulnerable to changes in rainfall patterns as monsoon rains are vital for it. Conventional irrigation methods often show inefficiencies, waste of water, and draining of groundwater supplies.
- ***Groundwater depletion:*** In places like Punjab and Haryana, too much groundwater has been taken for agriculture, lowering water tables. Small and marginal farms define India's scattered land holdings, which require assistance in implementing modern agricultural practices and achieving economies of scale. Population increase and inheritance rules help to cause later land fragmentation, hence reducing output.
- ***Low Productivity:*** Many farmers still need to improve their farming methods, which show less output than modern ones. Inadequate availability of fertilizers and better seeds reduces agricultural output. Using chemical fertilizers and pesticides excessively has degraded the quality and fertility of the soil. Unsustainable farming methods produce effects, including soil erosion and loss of topsoil, reducing soil fertility.
- ***Not enough technological accessibility:*** Small-scale farmers often lack the financial wherewithal to purchase modern machinery, which leads to agricultural techniques primarily dependent on hand work. The digital divide describes the limited availability of digital tools and platforms, which hinders the efficient application of precision agriculture.
- Farmers face uncertainty resulting from the erratic changes in market prices for their agricultural products, which affects pricing issues and market access. Middleman dominance exploits farmers by cheap pricing and obtaining a large share of their income.
- Insufficient transportation and storage facilities cause losses after harvest.
- ***Climate Change: Severe Storms:*** Agricultural suffers from the increased frequency of storms, floods, and drenches. Temperature variations affect the cycles of development and agricultural output.
- ***Credit and financial restrictions:*** Many farmers depend on unofficial lenders as formal credit is not readily available, which drives outrageous interest rates and runs the danger of entering debt traps.
- ***Insurance Challenges:*** Their efficacy has to be raised

since crop insurance programs expose farmers to possible financial losses.

- ***Policy and Governance Issues:*** Regular policy changes in agriculture leave farmers confused and uncertain. There needs to be more means of subsidy distribution to ensure money flows to the designated beneficiaries.
- Farmers often require additional knowledge about ideal techniques, sustainable agriculture, and market-relevant information, so farmer education and training are important. Another issue is the insufficient supply of extension services. More services are needed to guarantee farmers' information and technology distribution. Crop vulnerability is the sensitivity of crops to diseases and pests, causing significant financial losses. Pesticide overuse has led to the emergence of resistance in particular insect populations.
- ***Post-harvest losses:*** Not Enough Storage Facilities: Not enough storage resources cause significant losses of perishable goods.
- ***Plastic waste management:*** The use of plastic in farming, such as in mulching and irrigation systems, has led to increasing plastic waste in rural areas, contributing to environmental degradation.

The need for more processing facilities reduces the feasibility of further activities.

IV. APLLICATION AREA OF LLM IN AGRICULTURE

Farmers without internet access can instantly gain from artificial intelligence armed with a basic SMS-enabled smartphone and the Planting App. Wi-Fi-enabled farmers can employ artificial intelligence tools to get an always-tailored AI-automated plan for their operations. Since artificial intelligence can adapt to several farming environments, farmers feel seen and catered to. Using IoT and based on artificial intelligence advances, farmers may efficiently meet the growing food demand while sustainably raising production and revenues, thereby avoiding the depletion of critical natural resources. We consider climatological factors such as temperature, precipitation, wind patterns, and sun radiation to make sure farmers have support in their activities. Retrieval-augmented generation (RAG) is a Generative AI (GenAI) design that improves the newly acquired accurate data from corporate systems and approved internal knowledge repositories. This development helps to produce more informed and consistent answers. A significant language model is a type of artificial intelligence used to understand natural language using deep learning methods. Extensive text sets are used to train it to find statistical relationships between words and phrases. It could generate text, translate material, and run other natural language processing tasks. Figure 1 illustrates RAG and LLM application generation.

Facebook AI Research (formerly Meta AI) filed the paper "Retrieval-Augmented Generation for Knowledge-Intensive Tasks" in 2020 with the abbreviation "RAG." The work defines RAG as a flexible fine-tuning formula connecting any Language Model inference (LLM) to any internal or outside data source. Retrieve-augmented generation is a technique meant to increase the relevance and dependability of the responses by including a data-retrieving component in the reply-generating process. The user's search indicates that a retrieval model finds and ranks the most relevant material and documents from appropriate sources. It then uses the Language Model's API to activate it and turns the query into an improved contextual cue. An instructive RAG analogy is a stock trader using real-time market updates and publicly available historical financial data. Equity traders inside a company make investment decisions by closely examining industry dynamics, financial markets, and company performance. Still, they use real-time market data and inside stock recommendations provided by their organization to maximize the most profitable deals. Retrieval-augmented generation (RAG) is a robust approach combining generative models with retrieval-based methods, benefiting contexts requiring exact information. RAG finds several uses in agriculture since it can efficiently retrieve and rebuild knowledge from large databases. RAG's possible uses in agriculture consist in:

A. Crop disease diagnosis and management

RAG systems help farmers identify agricultural diseases by capturing pictures of diseased plants and thoroughly describing symptoms. The RAG model retrieves relevant database information, including thorough agricultural knowledge, research publications, and disease recommendations. It then generates exact advice on disease identification, available treatment choices, and preventative measures.

- ***Advantage:*** Giving accurate, real-time information that fits a circumstance helps identify early disease and lowers crop production loss.

B. Suggestions for pest control Use Case

Farmers dealing with pest infestations can upload pictures or describe the bugs using a RAG technology-operated system. The system generates helpful advice on controlling or eradicating similar pests using environmentally friendly methods or chemical treatments by extracting data about such pests from databases.

- Benefits include environmentally friendly farming methods, reduced pesticide application, and focused, accurate pest control methods.

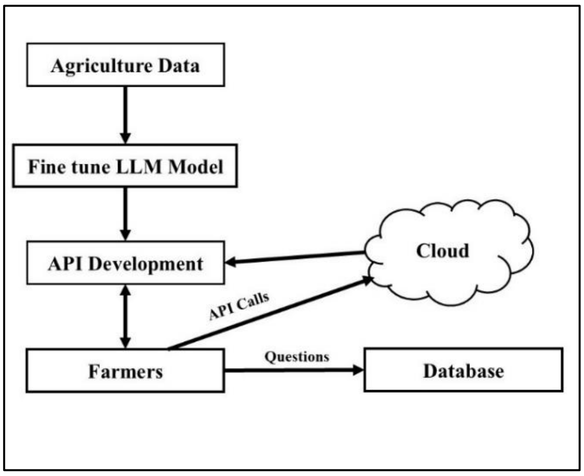

Figure 1: Application Methodology

- Farmers can get recommendations for precision farming by entering relevant information about their soil conditions, climate, crop kinds, and other environmental variables. The RAG model extracts extensive information from agronomic research sources and offers custom recommendations on the best times for planting, irrigation plans, and nutrient management methods.

- Benefits include better agricultural output, resource preservation, and operational optimization of farms.
- Impact Study and Forecast of Weather Remote Agro forestry (RAG) system may provide exact atmospheric forecasts and evaluate their likely impact on certain crops. Relevant meteorological data and studies direct preparation for unfavorable weather conditions, including frost, drought, or too much precipitation.
- ***Benefits:*** Helps farmers implement preventive plans to protect their crops, therefore reducing the possibility of agricultural environmental damage.
- Ecological Methods of Agriculture Farmers looking to implement sustainable practices can use an RAG model to obtain and present thorough information on integrated pest management, organic farming techniques, or crop rotation. The system provides recommendations based on empirical studies and present scholarship.
- Benefits include less pesticide reliance, better soil fertility, and ecologically sustainable agriculture.
- Agricultural Education and Training • Use Case: RAG's current, spatially customized educational tools help to improve agricultural extension services. The system lets farmers and other rural laborers ask for best practices, new technologies, or market trends and get tailored synthesized answers depending on their particular needs.
- Benefits include improved agricultural knowledge, knowledge transfer, and constant learning enhancement.
- RAG uses data on market demand, pricing trends, and logistical direction to help distributors and farmers improve the effectiveness of their supply chains. It creates systems to maximize financial returns, reduce inefficiencies, and optimally distribute products.
- Benefits of this method include improved farmers' market access, cost-cutting, and supply chain optimization.
- RAG models allow farmers to depict or provide thorough explanations of suggestive indications visually, therefore identifying crop nutrient deficits. The program offers some fertilizers or soil additions and gathers relevant data. The benefits include improved crop health, assured balanced nutrition, and best use of fertilizers.
- RAG can help farmers adjust to changing climatic conditions by providing knowledge on crops adaptable to climate change and offering direction on adaptive farming techniques.
- This strategy's benefits include guarantees of food security, increased resistance to climate change, and support of sustainable agriculture. Combining RAG models with IoT sensors allows novel irrigation systems to retrieve real-time soil moisture data and weather forecasts. It generates ideal irrigation plans to maximize water usage and ensure crop health.

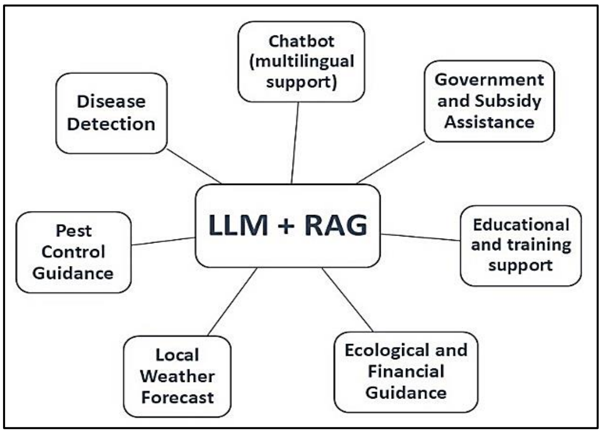

Figure 2: Applications of LLM + RAG in Agriculture Sector

- The Bhashini platform, combined with Large Language Models (LLM) and Retrieval-Augmented Generation (RAG), can significantly enhance the agricultural sector by providing multilingual support for farmers across India. By leveraging LLMs and Bhashini’s AI-driven language translation capabilities, farmers can access crucial information, such as best farming practices, weather forecasts, pest control methods, and government schemes, in their native languages. RAG enables real-time retrieval of localized, relevant data from diverse sources, ensuring farmers receive accurate, context-specific advice. This integration can bridge the digital divide, enhance communication between agricultural experts and farmers, and foster better decision-making, ultimately improving productivity and livelihoods in rural areas.
- ***Benefits:*** reduces running costs, lowers water consumption, and increases agricultural output.

V. CONCLUSION

By utilizing RAG in various applications, the agricultural industry can gain advantages in terms of enhanced efficiency, sustainability, and production. This will enable farming methods to be better informed and adaptable to the requirements of contemporary agriculture. This study has explored the transformative potential of Large Language Models (LLMs) within the agricultural sector, highlighting their capacity to address various challenges modern farmers face. By leveraging advanced natural language processing, LLMs can facilitate crop management, soil analysis, pest control, and supply chain optimization while providing personalized recommendations on sustainable farming practices and market trends. Furthermore, integrating LLMs with domain-specific knowledge through retrieval-augmented generation (RAG) enhances their applicability, allowing for context-aware and region-specific advice. As agriculture becomes increasingly data-driven, LLMs represent a powerful tool for improving productivity, promoting sustainability, and supporting decision-making. However, realizing their full potential requires addressing challenges related to data availability, model interpretability, and the need for localized solutions. Future research should focus on refining these models to meet the unique needs of diverse agricultural communities, fostering innovation in precision farming, and ensuring equitable access to such technologies.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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ABOUT THE AUTHORS

Saikat Banerjee is currently engaged in the pursuit of his Ph.D. in Computer Science at the University of Burdwan, located in Burdwan, West Bengal, India. He obtained his Bachelor of Science degree with a specialization in Computer Science, as well as his Master of Computer Application (MCA) award in 2013, from the University of Burdwan in West Bengal, India. He possesses over a decade of teaching experience. He has published multiple articles in various reputable journals and conferences. He is currently employed as a teacher of Computer Applications at Vivekananda Mahavidyalaya, a state-aided college. His research interests encompass a variety of topics, such as deep learning, soft computing, artificial intelligence, and machine learning.

Soumitra Das completed MSc in Computer Science at the University of Burdwan in Burdwan, West Bengal, India. He earned his Bachelor of Computer Application in 2022 from the Kazi Nazrul University in West Bengal, India. He has more than two years of development and data analysis experience. He has authored numerous publications in several esteemed journals and conferences. He is presently a software developer and machine learning enthusiast. His research interests include deep learning, soft computing, artificial intelligence, and machine learning.

Dr. Abhoy Chand Mondal is presently a Professor and Head at The department of computer science, The University of Burdwan in Burdwan, West Bengal, India, where he also serves as the Head of the Department of Computer Science. In 1987, he graduated with a Bachelor of Science degree in Mathematics with an honours designation from The University of Burdwan. In 1989 and 1992, respectively, he earned a Master of Science degree in Mathematics from Jadavpur University. In 2004, he graduated with a doctoral degree from Burdwan University. He also has 26 years of experience teaching and doing research in addition to his one year of work experience in the sector. More than 110 articles were published, and more than 60 journals were published. His areas of study interest include fuzzy logic, soft computing, document processing, natural language processing, natural language processing, big data analytics, machine learning, deep learning, and other areas