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Transforming Animal Science through Artificial Intelligence (AI)

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In this modern era of the industrial revolution 4.0, almost all activities of human life cannot be separated from the use of information technology (IT) as an enabler for other activities and services. IT is no longer just a tool and is now a required component that must be owned. Its advancement, which significantly facilitates human life activities, has resulted in a high reliance on the existence of information technology (Rahmatullah *et al*., 2022). In addition, since technology plays a much more significant role in the digital era than it did in previous generations, today's generation is technologically literate. The rise in literacy, combined with recent technological advancements, has resulted in expanding technology in education. These are the generations entering the classroom today, ranging from millennials to Gen-Z, and they all share distinct characteristics that define their age. These generations expect to be actively engaged in their learning and do not perform well as passive learners. As a result, technology must be embraced in today's education, and teachers must incorporate technology into their students' learning (Hashim, 2018). Rapid advances in big data and artificial intelligence technologies have profoundly impacted all aspects of human society, including the economy, politics, science, and education. Artificial intelligence (AI), a machine-based technique with algorithmic power for making predictions, diagnoses, recommendations, and decisions, has gained prominence in the educational community in recent years due to its potential to support learning in various contexts. With diverse applications such as intelligent tutors for content delivery, feedback provision, and progress supervision, the field of AI in education has demonstrated technological advances, theoretical innovations, and successful pedagogical impact. Up until 2010, cultivators required to monitor their fields and spot flaws using the Global Positioning System (GPS), satellite maps, ground-based sensing platforms, and local sensing tools like data recorders. Digital agriculture (DA) and smart farming techniques moved toward digitalization with the advent of Unmanned Aerial Vehicles (UAV), low-powered long-range wireless sensors, Internet of Things (IoT) devices, and robotics (Basso and Antle, 2020). They contributed to the economic development and sustainability of food production. Indian farmers are predominantly small holder farmers (SHFs), and there are more than 40 critical farming activities that need attention and decision support to ensure good yields and returns on investment. New and emerging technologies such as the internet of things (IoT), drones, mobility, cloud computing, big data, remote sensing, artificial intelligence (AI), machine learning (ML), image analytics and processing, block chain, and agribots are poised to transform traditional agriculture into data-driven precision farming to generate sustainable profits (FICCI, 2022). Digital technologies can create promising business opportunities in agriculture and at this juncture, farmer has to be made a partner in the emerging business space from the start. It will not be an easy task given socio-political-economic conditions prevailing in the country.

Aims of artificial intelligence (AI)

Enhanced Efficiency and Automation: AI is designed to automate repetitive and mundane tasks, freeing up human resources to focus on more complex and creative endeavors. This leads to increased efficiency and productivity in various industries and domains.

Data Analysis and Decision-Making: AI can process and analyze vast amounts of data quickly and accurately, providing valuable insights and supporting data-driven decision making. This helps businesses and organizations make informed choices to improve processes, strategies, and outcomes.

Prediction and Forecasting: AI can predict future outcomes and trends based on historical data and patterns. This predictive capability helps in planning and strategizing for the future, whether in financial markets, weather forecasting, or customer behavior.

Personalization and Tailored Experiences: AI enables personalized experiences by understanding and adapting to individual preferences and behaviors. This applies to various aspects, such as personalized recommendations in e-commerce, content customization, and adaptive learning.

Problem-Solving and Optimization: AI can solve complex problems and optimize processes by evaluating numerous variables and finding the most efficient solutions. This is particularly useful in areas like logistics, resource allocation, and manufacturing.

Natural Language Understanding and Communication: AI, especially Natural Language Processing (NLP), allows machines to comprehend, process, and generate human language. This facilitates effective communication, chatbots, language translation, and more.

Enhanced Safety and Security: AI contributes to safety by monitoring and predicting potential risks in various domains, including cybersecurity, public safety, and autonomous vehicles.

Creative and Artistic Expression: AI can generate creative content, such as music, art, and writing, showcasing the potential for collaboration between human creativity and machine intelligence.

AI in Livestock Management

Accurate prediction of animal weight, which is crucial for improving the efficiency and sustainability of livestock management practices, often involve labor-intensive procedures and lack instant and non-invasive solutions. The application of AI in livestock management eliminates the need for physical contact, improves animal welfare and also mitigates potential risks. For instance, machine learning algorithms have been employed to forecast livestock supply and outputs, automatically classify cow behavior, and predict livestock weight. In the area of genomics, machine learning models have been utilized to identify cattle breeds using SNP panels, showcasing its potential for advancing livestock genetics. Overall, the studies highlight the power of AI in optimizing farming processes, reducing costs, and improving sustainability in livestock production.

Fig. 1: Applications of AI in Livestock

Genetics and AI

Through the application of machine learning models, scientists can analyze extensive datasets to forecast genetic traits, enhance breeding programs, and boost disease resistance. These studies span a range of applications-from predicting genomic traits in livestock like cattle and chickens to pinpointing crucial genes within animal models—highlighting AI's vital role in accelerating research progress and improving accuracy in livestock management. Machine learning supports the discovery of intricate patterns and associations within genetic data,

making it a critical tool for enhancing breeding program efficiency and promoting progress in animal biotechnology. The integration of AI in genetic research not only drives productivity but also supports sustainable agriculture and the preservation of important genetic resources in animal populations.

Embryo Transfer and AI

Embryo transfers are prone to errors, inconsistent manual grading of bovine embryos, and embryologist unavailability, particularly in the cattle business where visual assessment and selection of embryos are done by embryologists. The incorporation of machine learning into one important development in animal biotechnology is the use of embryo transfer methods. When paired with machine learning algorithms, spectroscopy and video microscopy in bovine reproduction are improving pregnancy success rates by allowing for more accurate forecasts of embryo viability and transferability (Shivani and Madan, 2024). These AI-powered devices are being used for more specialized purposes, like checking for toxicity to embryo-fetal development, on species other than cattle, like Iberian ribbed newts (Saiki *et al*., 2024).

Selective Breeding and AI

Despite the fact that genomic selection in animal breeding has been revolutionized by modern genotyping methods, the vast marker datasets have many limitations with regard to computational capacity, accuracy, and flexibility. Because machine learning algorithms are so flexible and can identify trends in big, noisy datasets, they present interesting solutions for animal breeding applications. Animal breeding is undergoing a revolution thanks to the use of machine learning into genomic research and selective breeding. Additionally, the use of AI and machine learning in bioinformatics simplifies the processing of genomic data, increasing the efficacy of selective breeding for a range of animal species. These developments are especially important for promoting sustainable farming methods and maximizing animal output and health.

Widely Used Automation in the Dairy Sector

Automation has assisted dairy farm owners in overcoming the challenges of locating workers willing to perform manual labor at dairy farms with the aid of lasers, sensors, and data collection. One benefit of automation is that animals appear to have adapted to this new technological trend and prefer robots.

Drones : Drones are quickly becoming an important tool in the dairy sector. While farmers are familiar with traditional technologies, they are increasingly calling for the use of drones to take on more complex tasks. For example, drones can be used to check fences and the herd in general, as well as to help herd cows from fields to barns. Furthermore, drones are being used by modern dairy farms to map, examine, and photograph pastures in order to monitor growth. The sophisticated algorithms powering the drones are even capable of recognizing cows specifically and distinguishing them from deer or other similar animals. This has been a great asset to the dairy industry, as it can help farmers save time and money by automating the process of herding cows. In addition, drones can be used to monitor animal health, identify and track diseases, and provide early warnings of potential issues. The data collected by drones can then be analyzed to improve herd management strategies. Taken together, the use of drones in the dairy sector has been a major boon for farmers, offering a host of benefits that would not be possible with traditional technologies.

Robots : Robots are becoming increasingly popular in the dairy sector, thanks to their ability to increase productivity, reduce labor costs, and improve biosecurity measures. The most common use of robots in the dairy sector is robotic milking machines or milk bots. These machines are designed to automatically identify the teats and milk of the cows, while also cleaning the udders. Milk bots have been found to be both efficient and time-saving, with some studies suggesting that they can reduce the time spent on milking by as much as 30%. Furthermore, they can also reduce labor costs, as they do not require human labor to operate. Robots can also be used to clean and sanitize the barn, improving biosecurity measures and creating a healthier environment for the cows.

Augmented Reality : Augmented reality (AR) is an innovative technology that enables the real-time blending of digital data with the environment experienced by the user. It has been found to be highly beneficial in many differ ent applications, such as increasing the visual appeal of food and accurately determining the right serving sizes. Furthermore, AR can also be used to monitor and assess cows for producers. For example, AR can provide farmers with real-time data on the health and well-being of their animals, allowing for more efficient and effective management of their livestock. Additionally, AR can be used to improve the accuracy of milk yield estimation and to better identify potential health issues. The use of AR in the agriculture industry has a number of potential benefits. For instance, it can help to reduce the labor costs associated with traditional methods of animal monitoring and assessment, while also providing more accurate data. Additionally, it can help to reduce the risk of human error when recording and analyzing data, thus improving the accuracy of results. Furthermore, AR can also be used to provide farmers with helpful information about their animals such as body temperature, body composition, and nutrition levels.

Challenges in the Use of AI in Animal Production Sciences

The application of artificial intelligence (AI) to the sciences of animal production is rife with difficulties, despite its enormous potential. The broad use and effectiveness of AI systems are constrained by several problems, which have technical, infrastructure, socioeconomic, and ethical components.

1. **Data-Related Challenges:** Effective AI models require large volumes of high-quality, labeled data for training. However, in animal production systems, data is often fragmented, inconsistent, or unstructured. For example, reliable datasets on animal behavior, health events, or environmental conditions are either unavailable or vary widely across regions. Wearable or embedded sensors used for collecting data on livestock health, behavior, and productivity may suffer from calibration issues, battery failures, or data loss, affecting the performance of AI algorithms (Rutten *et al*., 2013).
2. **Technical and Integration Barriers:** Animal physiology and behavior are influenced by multifactorial interactions involving genetics, nutrition, environment, and management. Capturing this complexity accurately through AI remains a technical challenge (Neethirajan, 2020). There is no universally accepted protocol for data collection, model training, or AI tool validation in animal sciences. This lack of standardization hinders interoperability and benchmarking (Gonzalez-Recio & Alenda, 2020). In rural or resource-poor settings, poor internet connectivity, lack of digital infrastructure, and unreliable power supply impede real-time AI applications.
3. **Cost and Economic Viability:** The implementation of AI technologies-such as smart sensors, data processing infrastructure, and software licenses requires significant capital, which is often unaffordable for smallholder farmers and developing countries. While AI promises long-term savings and productivity gains, many farmers are hesitant to adopt it due to uncertainty about the return on investment, especially in variable market conditions.
4. **Human and Knowledge Barriers:** Farmers and animal science professionals often lack the necessary technical skills to operate AI systems, interpret outputs, or troubleshoot hardware/software issues (Aung *et al*., 2020). Traditional mindsets and reluctance to adopt new technologies persist in many farming communities, especially where AI is perceived as complex or threatening to jobs.
5. **Ethical and Regulatory Concerns:** While AI can promote animal welfare through better monitoring, excessive surveillance may raise ethical questions about autonomy and natural behavior (Cang *et al*., 2020). Issues of data ownership, privacy, and misuse are emerging concerns, particularly when data is collected by third-party commercial platforms without transparent agreements.

Conclusion

The rapid evolution of machine learning and artificial intelligence in animal biotechnology marks a significant shift toward more efficient, data-driven approaches to managing livestock and improving agricultural productivity. Traditional methods employed in various domains of Animal Biotechnology, often involve procedures which are time-consuming, expensive, labor-intensive, stressful, inconsistent, lack instant and non-invasive solutions. The application of AI and ML in Animal Biotechnology not only enhance traditional methods but also provide novel solutions for challenges such as disease detection, breeding optimization, environmental sustainability, reducing failures and costs as well as improving efficiency.

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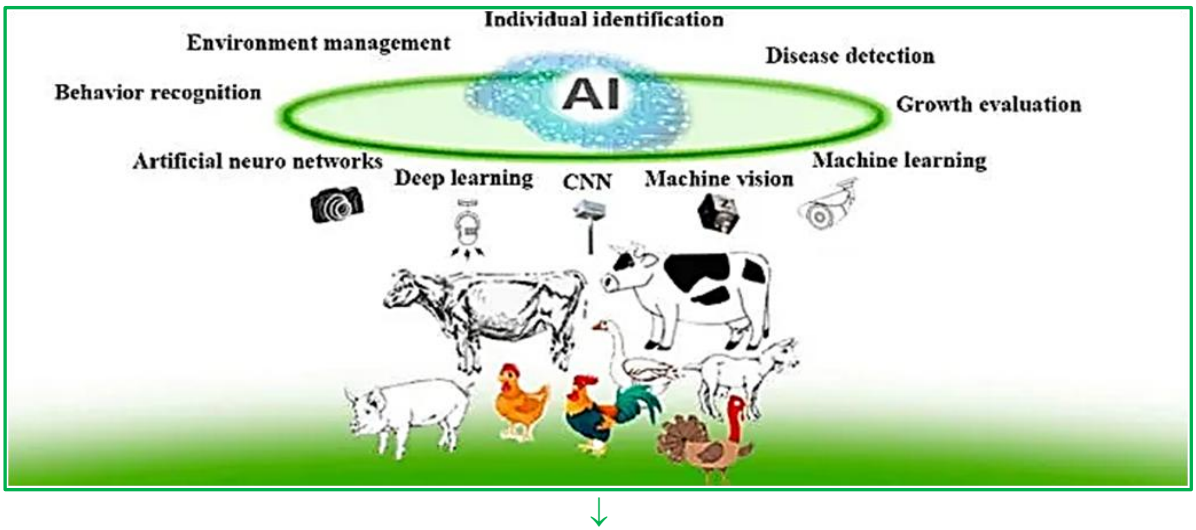

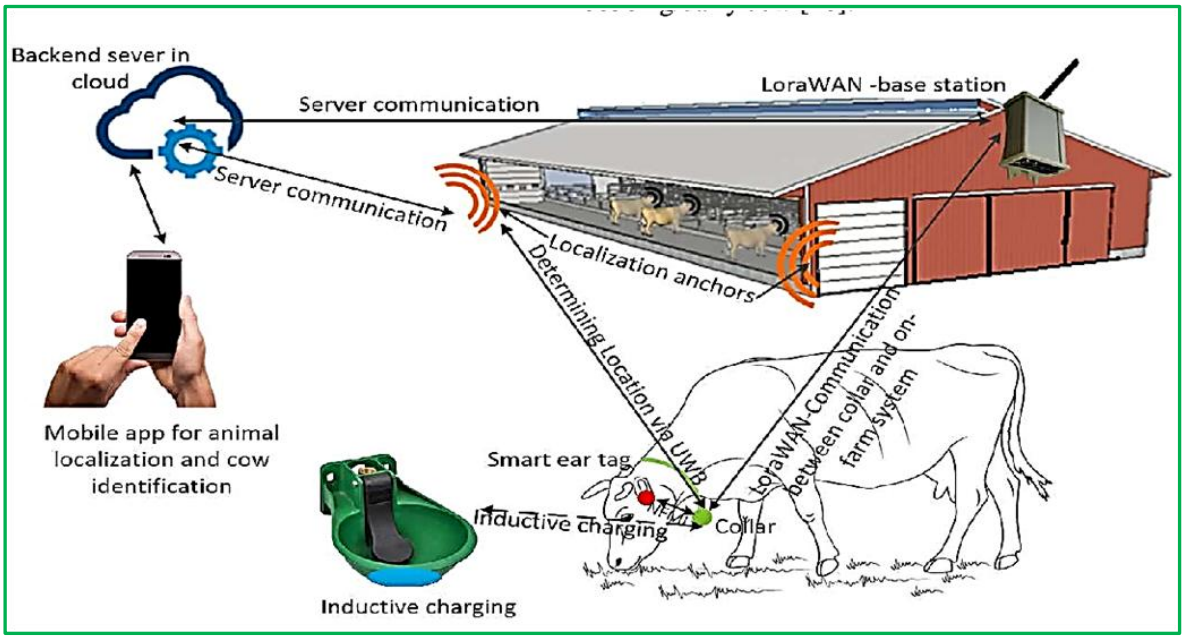
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