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Artificial Intelligence in Livestock Farming: From Smart Monitoring to Smarter Animal Management

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Introduction:

Livestock farming has always depended heavily on observation and experience. Farmers learn to recognize subtle changes in an animal's appetite, movement, appearance, behaviour and productivity. Veterinarians use clinical examination and diagnostic tests to identify disease, while farmers make daily decisions about feeding, breeding and herd management based on years of practical knowledge. However, as livestock farms become larger and production systems become more complex, continuously monitoring every individual animal is becoming increasingly difficult. This is where Artificial Intelligence (AI) is emerging as a powerful decision-support technology. Advances in Computer Vision, Machine Learning, Deep Learning, Internet of Things (IoT), smart sensors, Edge AI and robotics are creating new possibilities for monitoring animals in real time. AI systems can analyse photographs, videos, movement patterns, environmental conditions and other farm-generated data to identify abnormalities, estimate body weight, monitor behaviour and support health and production decisions. The objective is not to replace farmers or veterinarians, but to provide them with timely and data-driven information for better decision-making.

Artificial Intelligence:

Artificial Intelligence refers to computer-based systems capable of learning patterns from data and using those patterns to make predictions, classifications or recommendations. In livestock production, the data may come from cameras, smartphones, wearable sensors, GPS devices, temperature sensors, rumination monitors, farm records or environmental monitoring systems.

The real strength of AI lies in its ability to process large amounts of information continuously. A farmer may be able to observe a few important changes in an animal during routine farm visits, but an AI-enabled system can potentially monitor the animal throughout the day. When AI is combined with sensor

technologies, it can identify deviations from an animal's normal pattern and generate an alert for further attention. This creates an opportunity to move livestock management from a largely reactive approach towards a more continuous, preventive and precision-based system.

Computer Vision:

One of the most promising applications of AI in livestock farming is Computer Vision. Humans naturally use visual information to assess an animal's health and physical condition. We can notice skin lesions, changes in body condition, abnormal posture or difficulty in walking. Computer Vision attempts to enable machines to identify similar visual patterns from images and videos. Modern Deep Learning architectures such as YOLO, Faster R-CNN, Mask R-CNN and Transformer-based models are increasingly being explored for livestock applications. These models can be trained to identify objects, body regions, lesions and other visual characteristics.

Such technology has potential applications in disease detection, lameness assessment, body-condition scoring and live-weight estimation. The increasing availability of smartphones and relatively low-cost cameras could also make image-based livestock monitoring more accessible than sophisticated conventional monitoring systems. However, the performance of these systems depends strongly on the quality and diversity of the images used for training. A model trained under controlled conditions may not perform equally well in real farms with poor lighting, dust, different breeds and partially hidden animals.

AI for Early Disease Detection:

Early disease detection is one of the most valuable opportunities offered by AI in livestock management. Detecting a disease at an early stage can allow timely veterinary examination and intervention, potentially reduce production losses and improve animal welfare. The work described in the literature includes the AI-DISA platform, developed for image-based detection of important bovine diseases such as Foot and Mouth Disease (FMD), Mastitis and Lumpy Skin Disease (LSD). The system allows users to upload animal images through a mobile application, after which Deep Learning models analyse the images and generate a disease prediction and advisory information based on expert-curated knowledge. YOLOv5 models were fine-tuned for lesion localization and classification, with different model variants evaluated for the task. Such systems could provide a rapid preliminary screening mechanism for farmers, veterinarians and field workers. However, AI-based image analysis should be considered a screening and decision-support tool rather than a substitute for veterinary diagnosis. Final diagnosis may require clinical examination, laboratory testing and professional veterinary judgement.

Wearable Sensors:

AI becomes even more useful when it is combined with wearable and smart sensing technologies. Livestock can be monitored using smart collars, accelerometers, GPS modules, temperature sensors and rumination monitors. These devices continuously generate information about an animal's movement,

activity and physiological or behavioural patterns. Machine Learning models can then analyse the information to identify deviations from normal behaviour. For example, a reduction in movement may be associated with illness, injury or lameness. Changes in rumination may indicate alterations in feeding behaviour or health status. Similarly, changes in activity patterns can provide useful information for reproductive management. Instead of relying only on occasional visual observation, farmers could therefore receive continuous information about individual animals.

Heat Stress and Reproductive Management:

Climate change and rising temperatures are increasing the importance of effective Heat Stress management in livestock. Heat stress can influence feed intake, production, reproductive performance and overall animal health. AI can potentially combine information from environmental sensors with animal-level data to identify conditions associated with heat stress. Temperature, humidity, animal activity, physiological measurements and historical farm information can be analysed together to support timely management decisions. AI-based monitoring can also support estrus detection by identifying changes in activity and behaviour associated with reproductive events. This could be particularly useful in larger herds where continuous individual observation is difficult. The value of such systems lies not simply in predicting a problem, but in providing sufficient time for the farmer or veterinarian to respond.

Precision Livestock Farming:

Traditional livestock management often involves making decisions for groups of animals. Yet individual animals differ in health status, nutritional requirements, reproductive performance and productivity. Precision Livestock Farming (PLF) aims to address this variation by continuously monitoring animals at the individual level. Information from cameras, sensors, farm records and environmental monitoring systems can be combined using AI to develop individual animal profiles. Such profiles could support more targeted decisions related to feeding, health, reproduction and production. Instead of providing the same intervention to every animal, the farmer can potentially identify which animal requires attention and what type of intervention may be appropriate. The fundamental principle is simple: the right animal, the right information and the right intervention at the right time.

AI for Animal Welfare Monitoring:

Modern livestock production must focus not only on productivity but also on animal welfare. Behaviour provides important information about the physical condition and comfort of animals. AI systems can combine video, audio, thermal images, movement data and environmental information to classify behaviour and identify unusual patterns. Changes in lying behaviour, feeding activity, movement, vocalization or social interaction may provide early indications of discomfort or stress. Such systems may support the identification of lameness, heat stress, aggression, abnormal movement and reduced feeding behaviour. Continuous monitoring could therefore help farmers respond to welfare problems earlier. This

represents an important shift in the role of AI—from a tool for maximizing production to a technology that can also support humane and welfare-oriented livestock management.

Edge AI:

A major limitation for digital agriculture in rural areas is unreliable internet connectivity. Conventional AI systems may depend on sending data to cloud servers for processing, which can be difficult when connectivity is weak. Edge AI provides a potential solution by allowing AI models to operate directly on local devices, cameras, smartphones or farm gateways. Data can therefore be processed close to where it is generated. This can reduce dependence on continuous internet connectivity and may allow faster responses. Edge AI could therefore be particularly useful for remote livestock farms where uninterrupted cloud connectivity cannot be guaranteed.

Image-Based Weight Estimation:

Regular weight measurement is important for livestock management, but conventional weighing requires animals to be brought to a weighing platform. This can require additional labour and may cause handling-related stress. The Pig Live Weight (PLW) application described in the literature demonstrates an alternative approach. A Convolutional Neural Network (CNN) model was developed to estimate pig live weight from two-dimensional images uploaded by users. The reported experimental results showed R^2 values ranging from 0.734 to 0.801, with 82% testing accuracy. Image-based weight estimation could support digital herd management, individual animal profiles and day-wise weight tracking. More importantly, non-invasive monitoring can reduce the need for repeated physical handling of animals. Nevertheless, such models need extensive validation across breeds, ages, body types, camera conditions and production environments before they can be considered reliable for widespread commercial use.

From Cattle to Dogs:

The application of AI is not limited to cattle and pigs. The literature also describes a canine disease detection system developed using image datasets collected through the National Image-Based Livestock Diagnostics (NIBLD) mobile application. A hybrid modelling approach based on class-wise supervised autoencoders was developed to capture disease-specific features. Multiple autoencoders generated latent representations that were subsequently used for classification. This work illustrates an important possibility: once appropriate image datasets and validated models are available, similar AI frameworks can potentially be adapted for different animal species and veterinary diagnostic applications.

AI as a Digital Assistant for Farmers:

The next step beyond disease detection is helping users interpret and act on information. The Shria Smart Heuristic Response-Based Intelligent Assistant described in the literature functions as a conversational AI layer supporting disease-detection workflows, advisory interpretation and application navigation. When integrated with systems such as AI-DISA and PLW, such an assistant can make AI-based

technologies easier to use. The potential becomes even greater when these systems are developed in regional languages and adapted to the terminology and production practices familiar to local farmers. A technically advanced AI system will have limited impact if its users cannot easily understand or operate it.

Robotics, Drones and Automated Livestock Management:

AI is increasingly being combined with robotics and automation. AI-enabled systems can support automated milking, feeding, barn cleaning, weight estimation and surveillance. Drones can also assist in monitoring large farms and livestock areas. The important distinction is that robotics provides the physical ability to perform a task, while AI can help determine what should be done, when it should be done and where attention is required. The integration of AI with robotics could therefore reduce repetitive labour, improve consistency and allow farm workers to focus more on animal care and management decisions.

Challenge:

Despite its enormous potential, AI is not automatically accurate. The performance of an AI model depends heavily on the data used to develop and validate it. Livestock datasets need to represent differences in breed, age, sex, disease stage, geographical location, lighting conditions, camera type, farm environment and production system. For example, an AI model trained using clear photographs of cattle taken under controlled lighting may struggle when presented with a photograph taken in a poorly lit rural shed where the animal is partially obscured.

Therefore, the development of large, diverse and accurately annotated livestock datasets is one of the most important requirements for reliable AI applications.

Infrastructure and Cost:

The benefits of AI should not be restricted to large commercial farms. India has a large population of small and marginal livestock farmers, many of whom operate under financial and infrastructural constraints. Cameras, sensors, Edge devices, cloud services and specialized hardware can involve substantial initial investment. Weak internet connectivity and unreliable electricity supply can further limit adoption. Therefore, livestock AI solutions for India should focus on low-cost, mobile-based, energy-efficient and field-friendly technologies. Smartphone-based applications may be particularly promising because smartphones are already widely used. If a farmer can use an existing device to capture an image and receive a validated preliminary assessment, the technology becomes more accessible.

The Human Side of Artificial Intelligence:

The success of AI in livestock farming will ultimately depend on people. Farmers, veterinarians, paraveterinary workers and extension personnel will need training to understand both the capabilities and limitations of AI systems. A disease prediction generated by an AI model should not automatically be treated as a confirmed diagnosis. Similarly, a sensor alert should lead to observation and appropriate professional assessment rather than unnecessary treatment. AI literacy must therefore develop alongside

veterinary and livestock-management expertise. The most successful model is likely to be a human-AI partnership, in which AI processes large volumes of information while farmers and veterinarians provide context, professional judgement and final decisions.

Data Privacy, Ethics and Animal Welfare:

As livestock farms become increasingly digital, questions about data ownership and privacy will become more important. Who owns the data generated by a farm? Who can access it? Can commercial companies use farmer-generated information? How should data be stored and protected? What happens when an AI system produces an incorrect prediction? These questions require clear policies and responsible data governance. There is also an animal-welfare dimension. Wearable devices and monitoring equipment must be designed so that they do not cause injury, discomfort or unnecessary behavioural changes. Technological progress should therefore occur alongside ethical and responsible innovation.

From Treatment to Prevention:

Perhaps the most important contribution of AI to livestock health is its potential to shift the focus from treatment towards prevention. An animal may not yet show obvious clinical signs, but its movement, feeding, rumination or other measurable behaviours may already be changing. If AI can identify such deviations early, it can alert the farmer or veterinarian to investigate the animal.

This creates a potential progression from: Treatment → Early Detection → Risk Prediction → Prevention. Such a transition could help reduce disease-related losses, improve treatment timeliness and strengthen animal welfare. However, these benefits depend on rigorous validation. AI predictions should be demonstrated to have practical value under real farm conditions before they are used for important management decisions.

Future:

The future of livestock AI is likely to involve the integration of multiple sources of information rather than relying on a single camera or sensor. A future system could combine camera images, wearable sensors, environmental data, production records, health history and reproductive information to create a more complete picture of an individual animal. This approach, often described as Multimodal AI, could provide more robust assessments because a decision would not depend on a single source of information. In such a system, every animal could potentially have a digital profile containing information about its growth, weight, health, feeding, activity, reproduction and productivity. The farm would therefore become not simply automated, but data-driven and continuously monitored.

Building AI for Indian Livestock Farming:

India offers enormous opportunities for livestock AI because of its large and diverse livestock population. At the same time, the diversity of breeds, climates, production systems and farm sizes makes

technology development particularly challenging. AI solutions designed for India must therefore be tested under real Indian conditions rather than relying only on laboratory datasets. Collaboration among ICAR institutes, veterinary universities, agricultural institutions, technology companies, startups, government departments and livestock farmers will be essential. The AI-DISA, PLW and Shria initiatives demonstrate how research can be directed towards practical applications in disease detection, image-based weight estimation and digital advisory systems. Together, such efforts contribute to the broader development of digital agriculture, One Health, animal welfare and sustainable livestock production.

Conclusion:

Artificial Intelligence is no longer merely a futuristic concept for livestock farming. It is already being explored for disease detection, behavioural monitoring, weight estimation, reproductive management, welfare assessment and automated farm operations. Its greatest strength is the ability to continuously process large amounts of information and identify patterns that may be difficult to recognize through occasional human observation. Yet AI is not a magic solution. Good data, scientific validation, affordable infrastructure, reliable connectivity, trained users and responsible data governance are essential for successful adoption. The future of livestock farming should therefore not be viewed as a competition between humans and machines. Instead, it should be seen as a partnership in which farmers contribute practical knowledge, veterinarians provide scientific judgement, and AI provides continuous data-driven intelligence. If developed and deployed responsibly, AI can help transform livestock management from reactive to preventive, from group-based to individual-based, and from experience-driven to evidence- and data-driven decision-making.

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