Wearable Sensors and AI - Real-Time Animal Health Monitoring

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The integration of wearable sensor technologies with artificial intelligence is steadily reshaping how animal health is monitored and managed across various settings from commercial livestock farms to pet care and wildlife conservation. These systems continuously track physical, behavioural, and environmental parameters, offering real-time insights that support early disease detection, reproductive health monitoring, and welfare assessment. As these devices gather data on movement, temperature, feeding habits, and sounds, AI algorithms analyze the patterns to identify deviations that may indicate stress, illness, or oestrus. This proactive approach helps reduce morbidity, improve productivity, and support better decision-making by veterinarians and farmers alike. In dairy herds, for instance, smart collars and activity trackers now play a pivotal role in mastitis detection and precision feeding. Similarly, in companion animals, these tools aid in monitoring sleep cycles, emotional well-being, and chronic conditions, even enabling remote health checks when pets are in boarding facilities. These innovations contribute to One Health initiatives by enhancing surveillance of zoonotic threats through cross-species data analysis. The key challenges, such as calibration, data privacy, and affordability, must be addressed to ensure wider adoption. The convergence of these technologies is not merely adding tools to the veterinary toolkit it is gradually redefining the practice itself.

Keywords: *Artificial Intelligence, Livestock health management, Precision livestock farming, Real-time animal monitoring, Veterinary telemedicine, Wearable sensors*

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Introduction

Artificial Intelligence (AI), combined with wearable sensor technologies, is revolutionizing animal health monitoring by enabling continuous, real-time tracking of physiological and behavioural parameters across livestock, companion animals, and wildlife (Neethirajan, 2023). These innovative technologies are redesigning the veterinary sector, offering data-driven tools that augment animal welfare assessment, early disease diagnosis, reproductive management, nutritional parameters, and zoonotic disease surveillance. AI systems can detect subtle signs of illness, stress, or oestrus by analysing large datasets- such as temperature, heart rate, movement, and sounds long before clinical symptoms appear. This helps in the reduction of morbidity, mortality, and economic losses. In the dairy sector, AI has already demonstrated superior diagnostic accuracy in mastitis detection (Vyas et al., 2019; Sharvanthika et al., 2024). AI-guided precision feeding systems help in optimizing the diets of animals, leading to improved health and productivity. The facial and sound recognition technologies help in judging the emotions of animals, thus their welfare. In reproductive health, wearable sensors and AI ensure accurate oestrus detection and pregnancy monitoring, improving breeding success. Its role in veterinary telemedicine is equally transformative, allowing remote diagnostics and faster response times. Globally, AI supports One Health initiatives by analyzing inter-species transmission risks of zoonotic diseases such as rabies or avian influenza through the integration of animal, human, and environmental data. AI and wearable sensors are not just augmenting traditional practices in veterinary sciences they are redefining them. These technologies pave the way for a more practical, hands-on, precise, and empathetic approach to animal care. This chapter explores the current scenario, significant applications, and future potential of AI and wearable technologies in creating more innovative, sustainable animal health systems.

Wearable Sensors-technologies and types

Wearable sensors are transforming animal health monitoring by enabling continuous, real-time tracking of physiological, behavioural, and environmental parameters. These devices are attached externally or implanted in animals to collect vital data through the Internet of Things (IoT) that can help the owner in making decisions related to animals' health for its welfare.

Classification of wearable sensors

Wearable sensors used in veterinary applications can be broadly categorized into biometric, motion, environmental, and ingestible/implantable types each designed to monitor specific health or behavioural indicators critical for proactive animal care.

- **Biometric Sensors:** Biometric sensors monitor vital signs like heart rate, body temperature, and respiration to detect early signs of stress or disease. Commercially available devices include CowManager®, Moocall®, and SmaXtec®, which are widely used in Europe, the USA, and increasingly in India for real-time herd monitoring.

- **Motion and Activity Sensors:** Motion and Activity Sensors, such as accelerometers, gyroscopes, etc., analyze movement patterns to detect lameness, oestrus, and behavioural changes. In organized cattle and buffalo farms, CCD cameras are currently used to monitor movement manually, which is labour-intensive. Replacing this with wearable motion sensors would provide real-time, automated data and reduce observational workload.

- **Environmental sensors:** Environmental sensors such as temperature, humidity, GPS, etc., help assess the external conditions affecting animal health and productivity. These are especially useful in aquaculture, where water quality parameters are monitored, and in automated biowaste composting units, where temperature and humidity are tracked to optimize vermicomposting processes using dung.

- **Ingestible and implantable sensors:** Ingestible and implantable sensors are placed inside the animal's body to track internal parameters such as gut pH, temperature, or microbial activity. They are valuable for conducting long-term physiological studies, particularly in ruminants, and open new avenues for microbiome research and chronic disease management.

Advancements in sensor miniaturization and integration

Recent developments in nanotechnology and micro-electronics have reduced the size of sensors, making them more durable and easier to integrate with animal-friendly devices. These compact sensors improve comfort and reduce stress, making them suitable for use in both small and large animal species, including wild animals and birds.

Communication technologies

Wearable sensors communicate data using technologies like Bluetooth, RFID, LoRa, IoT, 5G, and satellite communication, enabling remote monitoring and seamless integration with farm management systems. These real-time communication networks support early disease alerts, geofencing, and performance analytics across connected livestock systems globally, even in remote or underserved areas where terrestrial networks may be limited.

AI Applications in livestock and companion animal health management

Early disease detection and predictive diagnostics: Artificial Intelligence (AI) is transforming animal health by enabling early disease detection and diagnostics. AI analyzes data from wearable sensors, behaviour, images, and environmental inputs to flag anomalies before clinical symptoms appear. In livestock, it detects mastitis, pneumonia, foot-and-mouth disease (FMD), and avian influenza by monitoring movement, temperature, and milk quality. Systems like PoultrySense, CowManager®, and Smart Collars automate this. Some models forecast outbreaks by analyzing humidity or wildlife patterns. Globally, the GLEWS+ program (FAO, WHO, WOAH) applies a One Health strategy for disease intelligence. FAO's EMPRES-i+ facilitates data sharing across 190 countries, while tools like EMA-i support real-time reporting. The RVF Early Warning Tool integrates environmental and outbreak data for better response (FAO). AI enhances diagnostics via imaging and behaviour analysis. Machine learning processes X-ray and MRI datasets to detect early cancer, mastitis, and respiratory infections. Smart collars detect appetite, motion, or vocalization shifts. In equine care, AI identifies early ocular diseases (Scharre et al., 2024). For tuberculosis, avian flu, and FMD, AI analyzes X-rays and behavioural cues. PoultrySense detects early avian flu signs; image analysis of hooves and behaviour aids FMD alerts (Mehta & Saini, 2024). In dairy, AI tracks somatic cell counts (Vyas et al., 2019; Tselios et al., 2024; Sharvanthika et al., 2024) and detects ketosis. AI also identifies parvovirus, African swine fever, and cancer in pets and pigs using thermal or behavioural data. Predictive analytics assess risk and guide interventions, aiding outbreak modelling and zoonotic tracking (European Parliament, 2025).

Reproductive health monitoring: AI is revolutionizing reproductive health management in animals by integrating data from wearable sensors, behaviour monitors, and diagnostic tools. These systems enhance fertility management by detecting oestrus and pregnancy early, thus improving breeding efficiency and animal welfare. Tools like SCR Heatime, Cowlar, and FitBark collars track behavioural signals such as increased activity and temperature shifts during heat cycles. AI algorithms analyze these inputs in real time to identify the optimal insemination window. In swine, Afimilk's systems detect behavioural and thermal changes to pinpoint standing heat (Afimilk, n.d.). AI also enables sound-based detection of estrus through analysis of vocal patterns in cows and dogs. For pregnancy, machine learning embedded in portable ultrasound tools (e.g., GE V-Scan, Samsung UGEO PT60A) can identify early markers even before fetal movement (Kim et al., 2025).

Wearables and RFID devices monitor shifts in feeding or movement, aiding continuous assessment. AI-driven analysis of hormonal biomarkers like progesterone and relaxin further supports early detection, especially in species like dogs. Platforms like CowManager and MooMonitor synthesize health and behaviour data to forecast breeding readiness and monitor pregnancy progression (Marques et al., 2024; Awoke Melak et al., 2024), making advanced reproductive monitoring scalable for farms of all sizes.

Nutritional and metabolic monitoring: AI-enabled feeders and wearable tech are transforming livestock nutrition. Smart systems track individual feed intake, rumination, and metabolic indicators to ensure optimal dietary balance. Deviations trigger AI-driven alerts or real-time diet adjustments to prevent conditions like ketosis, acidosis, or milk fever. Milk analysis tools such as Smart Scan and LactoCheck use AI to assess fat content and ketone levels, predicting metabolic disorders before symptoms emerge (Satoła & Bauer, 2021). AI also interprets body condition via imaging and drone-based surveillance, helping detect undernutrition or imbalance across herds (Summerfield et al., 2023). In pigs and dairy cattle, AI models integrate genetics, growth history, and feed efficiency data to tailor precision feeding (Piccioli-Cappelli et al., 2019; Barrientos-Blanco et al., 2020; Castillo-Arceo et al., 2024). The tailored diets help maintain optimal body condition in sows, increasing the success rate of pregnancies and improving piglet health (Pomar & Remus, 2019).

This precision feeding approach not only enhances reproductive outcomes but also supports better resource utilization and reduces feed waste. Pet care also benefits platforms like Optisol and Celeritas Digital customize diets using activity and health metrics, helping manage obesity and prevent chronic illnesses (Intelligence. 2023). In equine health, wearable sensors paired with AI can monitor heart rate, activity, and glucose levels to predict and manage Equine Metabolic Syndrome (EMS) and laminitis (Feuser et al., 2022).

Welfare and stress monitoring: AI plays a vital role in detecting animal stress and enhancing welfare. Systems like SmartBow, Afimilk, and CowManager use sensors and cameras to monitor rumination, vocalization, heart rate, temperature, and cortisol levels, providing early alerts for illness or stress (Fatoki et al., 2024). Tripartite sensors in pigs (Neethirajan & Kemp, 2021; Neethirajan, 2023), HRV tools in horses, and AI-driven monitors in poultry detect crowding, aggression, or heat stress (Mitchell & Schwarzwald, 2021). In zoos, platforms like YOLO enable non-invasive observation, while facial recognition estimates emotional states in dogs and horses. AI also aids in optimizing feed formulations, reducing waste and environmental impact (Cruz et al., 2024; Taleb et al., 2024). Broader platforms like Agri-Tech's Livestock Welfare Monitoring and ZooMonitor AI integrate physiological, behavioural, and environmental data to predict welfare risks (Wark et al., 2019). From farms to aquariums, AI enables proactive care, improving both animal well-being and management efficiency.

AI-Enabled wearables in companion animals

Wearable sensors and AI algorithms are used to track sleep cycles in both pets and livestock, detecting irregularities that may indicate discomfort, anxiety, or illness. For companion animals, disturbances like frequent waking or restless behaviour during sleep can be linked to conditions such as chronic pain or emotional stress. These insights can be shared with veterinarians or pet owners for early diagnosis and treatment. Similarly, in cattle, disrupted sleep patterns may point to environmental stress or health issues like mastitis, allowing farmers to intervene promptly and maintain herd health.

Remote health monitoring for pets: In Metro cities, pet hostels are thriving businesses. People go on tours, leaving their pets in these hostels, but they want to monitor their pets when they are out of the station. Such devices are handy in that area.

AI-assisted behaviour analysis: More and more people are keeping cats and dogs as companion animals, but they have no idea about the hormonal cycle of these animals. Such tools can help the owner in analyzing the behaviour of animals.

Veterinary telemedicine and ai diagnostics: NITI Aayog has published a framework and guidelines for Telemedicine for Livestock Health & Safety in 2023 (NITI Aayog, 2023).

Challenges and limitations

While wearable sensors and AI systems hold immense potential to revolutionize animal health monitoring, several technical, economic, ethical, and operational hurdles still limit their widespread adoption and impact.

Data accuracy and sensor calibration: Accurate data collection is the backbone of real-time animal health monitoring (Asmare, 2022). Sensors tracking temperature, heart rate, movement, and feeding patterns must be calibrated appropriately; otherwise, they risk false alerts or missed diagnoses (Shajari et al., 2023). However, unlike human health devices such as glucose monitors that offer auto-calibration or code entry animal sensors often lack user-friendly recalibration protocols (Ghosh et al., 2025). This makes them less practical, especially in rural or low-resource farm settings (John et al., 2024). Additionally, environmental factors like dust and moisture can degrade sensor performance. Discomfort caused by bulky or poorly placed devices can also affect animal behaviour and data reliability. Research is ongoing to improve sensor comfort and functionality using advanced materials, biosensors, and automated recalibration tools.

Algorithmic limitations and interpretation: AI-powered systems depend on extensive, diverse datasets for accuracy. However, many models are trained on limited regional data, making them less reliable in other environmental or physiological contexts. Without proper interpretation frameworks, even accurate data can lead to misguided decisions. There is a pressing need for adaptable algorithms that can handle varied species, conditions, and geographies (Young & Brown, 2023; Taylor et al., 2024).

Security, privacy, and ethics: The digitalization of animal farming brings privacy and cybersecurity concerns that are often overlooked in the rush for innovation. Who owns the animal data farmers, tech providers, or third parties? How is it protected from misuse or cyberattacks? As animal monitoring becomes cloud-based, strong encryption, secure data ownership protocols, and safeguards against misinformation are vital. Ethically, there is also concern over the objectification of animals, treating them as mere data points rather than sentient beings. Over-reliance on automation could weaken the human-animal bond, especially in systems that remove caretakers from daily interactions (Neethirajan, 2023).

Cost and scalability: High upfront costs of sensors, data platforms, and connectivity infrastructure hinder adoption, particularly for smallholders (Goodwin & Gouldthorpe, 2013). Most systems rely on expensive imported silicon chips and require technical expertise, making them less accessible in developing or remote regions. Indigenous solutions like modular sensors, open-source hardware, and localized chip production could lower costs and foster innovation. Examples such as India's INAPH and MooSense platforms show how locally built tools can enable real-time health tracking while being economically viable (Sarangi et al., 2014).

Integration with existing systems: Many small and mid-sized farms lack the digital infrastructure to integrate advanced monitoring tools seamlessly. High sensor costs, unstable internet, and limited technical training widen this digital divide. Farmers may struggle to interpret complex data without guidance, undermining the tech's potential. Community-based models where sensor hubs are shared, or government-supported training and subsidies can bridge these gaps. Affordable, scalable devices coupled with targeted education will be key to making innovative livestock management inclusive and effective.

Conclusion

The future of animal health monitoring lies in integrating AI, biosensors, and autonomous systems to improve welfare, reduce costs, and boost productivity. Technologies like the STAR robot outperform humans in surgeries, while AI enables real-time disease detection, reproductive tracking, and precision feeding. These innovations offer actionable insights, especially beneficial for large farms and smallholders alike. Realizing their full potential demands supportive policies, digital infrastructure, and farmer training. With ethical safeguards and scalable tools, AI-driven systems promise sustainable, efficient, and data-driven veterinary care, transforming animal health practices and empowering farmers across resource settings.

Conflicts of interest

The authors declare no conflicts of interest.

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