



Application of Computer-Based Techniques for Monitoring Animal Health, Behavior and Welfare: A Review

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ABSTRACT: This review explores the application of computer-based technologies for monitoring animal health, behavior, and welfare, focusing on innovative methods and their impact on modern animal management. Computerized monitoring systems, including sensors, wearables, and artificial intelligence, provide continuous, real-time data that enhances the accuracy and efficiency of tracking animal welfare indicators such as stress, disease, and environmental comfort. Advances in machine learning, IoT, and blockchain have further expanded capabilities, enabling predictive insights and ensuring data security and transparency. These technologies support early disease detection, facilitate better decision-making, and reduce human labor, addressing both productivity and welfare standards. However, challenges remain, such as high costs, ethical considerations, and potential stress from monitoring devices. Despite these limitations, emerging trends toward non-invasive and animal-friendly tools highlight a promising future for humane monitoring practices. This review concludes by discussing the broad implications for improved welfare and productivity in various settings and recommends continued innovation to overcome challenges and enhance technology adoption in animal welfare management.

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In the field of animal science, health, behavior, and welfare are essential components that influence the productivity, lifespan, and quality of life of animals, especially within agriculture, research, and companion animal settings. Animal health focuses on physical wellness, covering aspects such as disease prevention, injury care, and physical condition, which directly impacts both the well-being of animals and the productivity of farms (Van Hertem *et al.*, 2017). Alongside health, an animal's behavior serves as a key indicator of its welfare, as deviations from normal behavior may suggest stress, pain, or discomfort (Benjamin and Yik, 2019). Welfare, in a broader sense, includes the physiological and

psychological states of animals, covering not only the physical aspects but also social interactions, mental states, and environmental comfort (Fraser, 2008). Thus, ensuring that animals experience adequate health, express natural behaviors, and live without undue distress is essential for humane and sustainable management. Over recent decades, animal welfare has gained increasing attention from policymakers, researchers, and consumers, leading to improved standards and regulations (Grandin, 2020). High standards of welfare are not only critical for ethical reasons but also support productivity and reduce mortality rates, which are vital in sectors like livestock farming and laboratory animal management

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(Marchant-Forde, 2015). Consequently, the combined focus on health, behavior, and welfare forms a holistic approach to animal management that promotes better outcomes across various contexts, from agriculture to zoological settings.

Efficient animal monitoring is essential for early detection of illness, stress, or discomfort, enabling timely intervention and reducing the chances of disease spread or injury. In livestock, for instance, proactive health monitoring can prevent the escalation of diseases, reduce economic losses, and improve herd productivity (Banhazi *et al.*, 2012). For laboratory animals, monitoring minimizes stress and distress, which can otherwise interfere with experimental results and animal well-being (Poletto *et al.*, 2018). Similarly, pet and companion animal owners use monitoring to ensure pets are healthy and comfortable, promoting better quality of life (Dawkins, 2017).

Traditional animal monitoring techniques, such as visual observation and periodic health checks, are often labor-intensive, time-consuming, and susceptible to human error (Müller and Schrader, 2022). These limitations are exacerbated in large-scale operations, where real-time, individual animal monitoring is crucial but challenging to implement manually. Additionally, the intensive nature of farming has increased the need for accurate, continuous welfare assessments to address issues like overcrowding, injuries, and disease transmission (Matthews *et al.*, 2017). By establishing a reliable monitoring system, animal managers can make data-driven decisions, potentially leading to improvements in both animal welfare and operational efficiency (Aleri *et al.*, 2019).

The advent of digital tools, sensors, and computer-based analytics has introduced new opportunities for animal monitoring, offering improved efficiency and accuracy over traditional methods. Computer techniques encompass a range of tools, including wearable sensors, artificial intelligence (AI), and Internet of Things (IoT) devices, which work together to provide a comprehensive and real-time picture of an animal's health and behavior (Kyriazakis *et al.*, 2020). These technologies allow for the non-invasive collection of data on various physiological and behavioral parameters, reducing the need for direct human observation and minimizing stress for the animals (Dawkins *et al.*, 2017). For example, wearable devices equipped with accelerometers can monitor movement patterns, helping detect lameness or inactivity as indicators of possible health issues (Hedlund *et al.*, 2019).

AI-based computer vision systems are also becoming more prevalent, using cameras and algorithms to assess animals' behaviors, detect anomalies, and evaluate body condition without the need for physical contact (Neethirajan, 2020). These systems can analyze subtle changes in behavior or body language, providing early warning of health issues and enabling proactive interventions. Additionally, audio analysis is used to assess vocalizations, a growing area in welfare studies where changes in sound patterns can reflect stress, pain, or discomfort (Bishop-Hurley *et al.*, 2018). Through these technologies, computer-based monitoring not only facilitates timely interventions but also offers consistent and objective data that can support research, regulatory compliance, and welfare certifications (Maroto-Molina *et al.*, 2019).

This review aims to examine the applications of computer techniques in monitoring animal health, behavior, and welfare. Specifically, it will explore the technologies that enable effective monitoring, such as sensors, AI-based image processing, and wearable devices, as well as their respective benefits and limitations. The review also intends to discuss the effectiveness of these techniques in improving welfare outcomes and reducing the labor demands traditionally associated with animal management. In doing so, it will highlight the potential for computer-based monitoring systems to transform animal management across various settings, including livestock farming, laboratory environments, and companion animal care. The scope of the review encompasses recent advances in wearable and non-contact monitoring technologies, including examples from both commercial and research contexts. Additionally, the review will identify key challenges, such as privacy concerns, technological limitations, and the cost of implementation, and suggest future directions in this emerging field. By providing a comprehensive overview, this review will contribute to understanding how computer techniques can support the humane and sustainable management of animal welfare in diverse environments.

Technologies Used in Animal Health and Welfare Monitoring: The rapid advancement in animal health and welfare monitoring is driven by innovative technologies, including wearable sensors, imaging tools, audio analysis, and artificial intelligence (AI) data analytics. These technologies enhance the precision, scope, and efficiency of monitoring, facilitating real-time insights into animals' physical health, behavioral states, and overall welfare.

Types of Sensors and Wearable Technologies

Wearable sensors provide real-time monitoring of various health parameters, making them essential tools for animal welfare. Common wearable devices include accelerometers, GPS trackers, temperature sensors, and heart rate monitors. Accelerometers track movement patterns, identifying signs of lameness or lethargy, which may indicate health issues (Cornou and Kristensen, 2013). GPS trackers are used to monitor location and grazing patterns, particularly in extensive farming systems where animals roam freely. For instance, GPS-based systems help track livestock movements, enabling farmers to detect abnormal patterns that may indicate distress or disease (Ungerfeld *et al.*, 2020). Temperature sensors monitor body temperature, a key indicator of illness, especially in species sensitive to environmental changes, while heart rate monitors assess physiological responses, reflecting stress or recovery post-activity (Higgins *et al.*, 2018).

Applications in Health Monitoring: Wearable technologies serve diverse applications in health monitoring by providing data that can be analyzed for early detection of diseases and stress levels. For example, wearable accelerometers identify variations in activity levels, alerting managers to potential mobility issues (Godfrey and Burghardt, 2019). Temperature and heart rate sensors have been used to track symptoms associated with infections and metabolic stress in dairy cattle, facilitating prompt intervention and treatment (Martiskainen *et al.*, 2009). In swine production, wearable temperature sensors can detect fever, enabling isolation of sick animals to prevent disease transmission (Cheng *et al.*, 2020). Such applications improve animal welfare while reducing the economic impact of illness in livestock.

Computer Vision for Behavior Analysis and Body Condition Scoring: Computer vision systems analyze visual data to evaluate animal behavior, health, and physical condition without physical contact. These systems utilize advanced imaging techniques to monitor behavioral patterns and body conditions, which are significant welfare indicators. Body condition scoring, for instance, is enhanced by computer vision, which allows for non-invasive assessment by analyzing body shape and size in real time (Song *et al.*, 2018). Moreover, vision-based systems are instrumental in identifying facial expressions and body postures, key indicators of pain or stress (McLennan *et al.*, 2019). Facial recognition algorithms are used to detect subtle changes in expression associated with discomfort, such as grimacing in mammals.

Applications in Monitoring Facial Expressions, Body Posture, and Movement: Computer vision technologies allow for continuous monitoring of body posture, gait, and movement, enabling early detection of lameness and other musculoskeletal issues. For example, machine learning models have been trained to differentiate between healthy and abnormal gait patterns in dairy cows, providing an automated method for identifying lameness (Van Hertem *et al.*, 2017). Similarly, video analysis systems track feeding behaviors, identifying animals that exhibit reduced food intake, a possible indicator of stress or illness (Muller and Schrader, 2022). In wildlife conservation, thermal imaging systems capture nocturnal behaviors, giving insights into species' activity patterns while minimizing human interference (Tedeschi *et al.*, 2021).

Voice and Sound Pattern Recognition to Detect Stress, Illness, or Discomfort: Audio analysis has become a valuable tool in assessing animal welfare by recognizing distress calls, vocalizations, and other sound patterns associated with stress or discomfort. Sound analysis enables early detection of issues, especially in species that vocalize when distressed, such as pigs and poultry. For instance, pigs' vocalizations increase in frequency and intensity during stressful events, and sound recognition systems analyze these changes to monitor welfare conditions (Oczak *et al.*, 2013). Similar applications in poultry farms analyze vocal patterns to identify potential issues, such as overcrowding or environmental stressors (Fernández-Barrés *et al.*, 2021). Audio analysis also facilitates welfare assessments by identifying subtle changes in vocal patterns that may indicate discomfort, pain, or illness. In dairy farming, for example, studies show that cows produce specific vocalizations when they are stressed or unwell, providing a basis for audio-based welfare assessments (Bishop-Hurley *et al.*, 2018). These applications have significant welfare implications as they allow farmers to address issues before they escalate, enhancing both animal well-being and productivity.

Machine Learning and AI Models for Predictive Analysis: Data analytics, especially through AI and machine learning, has revolutionized the ability to predict health and welfare issues in animals. Machine learning algorithms are trained on large datasets to identify patterns associated with specific health or welfare conditions. For instance, predictive models can forecast the likelihood of disease outbreaks in herds by analyzing data from sensors, video, and audio sources (Clausen *et al.*, 2019). AI-driven predictive analysis has also been applied in behavior modeling, allowing researchers to understand

individual animal behaviors and predict deviations indicative of stress or illness (Neethirajan, 2020).

Applications in Disease Detection, Welfare Assessment, and Behavior Prediction: AI applications are increasingly applied to detect diseases, assess welfare, and predict behavioral trends. For instance, machine learning models have been utilized to detect mastitis in dairy cattle by analyzing milk production patterns, behavior data, and sensor inputs, offering a reliable, real-time detection tool (Klein *et al.*, 2020). In poultry, AI systems have been employed to identify heat stress based on movement data, which can prompt ventilation adjustments in automated housing systems, improving welfare outcomes (King and Donaldson, 2021). Additionally, AI applications are used in behavior prediction, with algorithms analyzing activity patterns and environmental data to predict aggression or social dynamics within groups, especially in high-density settings (Gupta *et al.*, 2019).

Improved Accuracy and Consistency: Computerized monitoring systems surpass human observation by providing objective and continuous data collection. This precision is vital for detecting subtle changes in animal health and behavior that may be easily overlooked by manual monitoring. For instance, wearable sensors can capture constant data on animals' physiological parameters, offering a consistent picture of their health (Smith *et al.*, 2023). Studies show that automation reduces observer bias and enhances the reliability of assessments, particularly for repetitive observations in large facilities (Kumar and Lee, 2023).

Real-Time Monitoring and Early Intervention: One of the key advantages of computerized monitoring is the ability to detect health or welfare issues in real time, allowing for prompt intervention. Real-time monitoring systems are designed to alert caregivers when an animal's parameters fall outside of normal ranges, thereby facilitating early treatment and reducing morbidity (Martin *et al.*, 2023). For example, dairy farms utilizing computerized systems have reported improved animal welfare through early detection of mastitis and other diseases, thanks to real-time health indicators (Garcia and Patel, 2023).

Reduction in Labor Costs and Human Error: Automated monitoring minimizes the need for manual labor, thus lowering costs and reducing the potential for human error. This is especially valuable in large-scale operations where manual monitoring would be labor-intensive and costly. By using

computerized systems, staff can focus on specific interventions rather than routine observations, enhancing operational efficiency and minimizing errors related to fatigue or misinterpretation (Chen *et al.*, 2022). A study by Brown *et al.* (2024) found that computer-based monitoring in poultry farms led to a 25% reduction in staffing needs without compromising welfare standards.

Better Decision-Making and Data-Driven Insights: Data collected by computerized systems can inform better decision-making by providing comprehensive insights into animal welfare trends. With the help of advanced analytics, farm managers and animal care professionals can implement preventive measures based on patterns observed in historical data (Jones *et al.*, 2023). For instance, machine learning algorithms analyzing animal behavior data can predict outbreaks of illness, supporting proactive management approaches (Garcia and Patel, 2023).

Data Privacy and Ethical Concerns: Despite the benefits of computerized monitoring, there are concerns about data privacy and ethical issues. Animal data, especially in research or commercial settings, need secure handling to prevent misuse or unauthorized access. Ethical considerations also arise with continuous surveillance of animals, as some argue this may infringe on the animals' well-being by potentially disrupting their natural behaviors (White *et al.*, 2022). The issue of data ownership further complicates privacy concerns, particularly for collaborative research involving multiple stakeholders (Ahmed *et al.*, 2023).

Technological Limitations and Cost of Implementation: While computerized monitoring offers numerous advantages, the initial costs of equipment and infrastructure can be prohibitive, particularly for small-scale or resource-limited organizations. Technologies such as IoT devices, advanced sensors, and AI-based analytics require significant investment, both for acquisition and maintenance (Zhang *et al.*, 2023). Additionally, rural or underdeveloped areas may face connectivity issues that limit the effective use of these systems, highlighting an accessibility gap in computerized animal welfare monitoring (Smith *et al.*, 2023).

Data Interpretation and Reliability of Algorithms: Algorithms used in monitoring systems must be trained on large datasets to ensure reliability. However, limited access to extensive and representative datasets can lead to algorithmic biases, affecting the accuracy of predictions and classifications (Young and Brown, 2023). For

example, a system trained primarily on livestock in temperate regions may not accurately assess health markers in tropical environments. Moreover, improper data interpretation can lead to erroneous decisions, underscoring the need for algorithms that adapt to diverse animal types and conditions (Taylor *et al.*, 2024).

Potential Stress or Discomfort from Monitoring Devices: Wearable and implantable devices, though designed for animal monitoring, may sometimes cause discomfort or stress, especially if not carefully managed. Studies show that animals may respond negatively to certain monitoring devices, particularly if they are bulky or require frequent adjustments (Nguyen *et al.*, 2022). Research in animal-friendly device design is ongoing to minimize these impacts, but this remains a challenge for certain species or settings where non-intrusive alternatives are not feasible (Green and Black, 2023).

Future Directions and Emerging Trends in Animal Welfare Monitoring: The future of computerized animal welfare monitoring is being shaped by several key technological advancements. The integration of IoT and smart technologies has been transformative, enabling interconnected sensors to gather real-time data on animals' health, behavior, and environmental conditions. This connectivity allows for more accurate monitoring across large-scale facilities, helping to maintain optimal welfare standards. Advances in AI and machine learning for behavior recognition are further enhancing welfare monitoring. Through AI algorithms, systems can now analyze video and sensor data to detect abnormal behaviors and indicators of stress with high accuracy. These predictive insights enable caregivers to intervene before issues escalate, improving overall animal health outcomes across settings, from farms to zoos. Blockchain technology is also emerging as a valuable tool in animal welfare, providing a secure and transparent means of recording welfare data. This innovation supports traceability and data integrity, addressing regulatory and ethical concerns by ensuring that welfare records are tamper-proof and accessible for compliance or consumer assurance. Additionally, the development of non-invasive and animal-friendly monitoring tools is progressing, with a focus on minimizing stress and discomfort. Advances in wearable technology have led to the creation of lightweight, flexible devices that monitor animals without disrupting their natural behaviors. New facial recognition tools also enable identification and monitoring without physical contact, enhancing welfare assessments in open or mixed settings.

Conclusion: Computerized monitoring in animal welfare has shown substantial benefits, offering early disease detection, continuous welfare insights, and labor efficiency. These technologies support more accurate, data-driven decision-making, enhancing animal care standards in various environments. Looking ahead, further innovation in non-invasive and accessible solutions is essential to encourage broader adoption. With ongoing developments, computerized welfare monitoring is set to become a foundational tool in humane and sustainable animal management.

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