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AI-Based Human–Animal Conflict Management System: A Review

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Abstract

Human–animal conflict has become a significant challenge in many regions due to urban expansion, deforestation, habitat fragmentation, and increasing interaction between wildlife and human settlements. Traditional monitoring and mitigation methods are often reactive, labor-intensive, and inefficient in preventing damage to crops, property, and human lives. Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), Computer Vision (CV), Internet of Things (IoT), and sensor networks have enabled the development of intelligent systems capable of real-time animal detection, tracking, classification, and early warning generation. This review paper presents a comprehensive analysis of AI-based human–animal conflict management systems. Various technologies, including deep learning models, image processing techniques, wireless sensor networks, thermal imaging, edge computing, and predictive analytics, are examined. The paper discusses current research trends, implementation challenges, datasets, performance metrics, and future directions for developing reliable and scalable wildlife monitoring solutions. The study concludes that AI-driven systems can significantly reduce human–animal conflicts while promoting wildlife conservation and sustainable coexistence.

Keywords: Human–Animal Conflict; Artificial Intelligence (AI); Machine Learning (ML); Computer Vision; Wildlife Monitoring; Internet of Things (IoT); Deep Learning; Animal Detection.

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Introduction

Human–animal conflict refers to interactions between humans and wildlife that result in negative impacts on people, animals, resources, or ecosystems. Such conflicts frequently occur near forests, agricultural lands, highways, and urban boundaries. Crop destruction by elephants, livestock predation by leopards, and wildlife–vehicle collisions are among the most common examples.

Rapid urbanization and habitat loss have increased encounters between humans and wild animals. Traditional mitigation approaches such as fencing, manual surveillance, and alarm systems often fail to provide timely responses. Artificial Intelligence (AI) offers innovative solutions through automated monitoring, object detection, behavior analysis, and predictive warning systems.

Recent developments in deep learning, computer vision, and IoT technologies have enabled intelligent wildlife monitoring systems capable of detecting animals in real time and alerting authorities or local communities before conflicts occur.

The objectives of this review are:

- To analyze AI technologies used in human–animal conflict management.
- To examine existing research and intelligent monitoring systems.
- To identify challenges and limitations of current approaches.
- To discuss future research directions.

Human–Animal Conflict: Causes and Impacts

Major Causes

- Deforestation and habitat destruction.
- Expansion of agricultural activities.
- Urban encroachment into wildlife corridors.
- Climate change and resource scarcity.
- Increased transportation infrastructure.

Consequences

Human Impact

- Injury and loss of life.
- Economic losses due to crop damage.
- Property destruction.
- Reduced livelihood security.

Wildlife Impact

- Retaliatory killings.
- Habitat fragmentation.
- Population decline.
- Increased stress and behavioral changes.

AI Technologies Used in Human–Animal Conflict Systems

Machine Learning

Machine Learning algorithms learn patterns from historical data and predict animal movement or intrusion events.
Common algorithms include:

- Random Forest
- Support Vector Machine (SVM)
- K-Nearest Neighbors (KNN)
- Decision Trees

Applications:

- Animal behavior prediction
- Risk zone identification
- Movement pattern analysis

Deep Learning

Deep Learning provides high accuracy in image and video analysis.

Popular models include:

- Convolutional Neural Networks (CNN)
- YOLO (You Only Look Once)
- Faster R-CNN
- SSD (Single Shot Detector)
- EfficientDet

Applications:

- Real-time animal detection
- Species classification
- Intrusion monitoring

Computer Vision

Computer vision systems analyze visual data from surveillance cameras.
Functions include:

- Object detection
- Motion tracking
- Thermal image analysis
- Behavior recognition

Internet of Things (IoT)

IoT devices collect and transmit environmental and wildlife data.
Components:

- PIR Sensors
- Ultrasonic Sensors
- GPS Modules
- Camera Modules
- Wireless Communication Systems

Benefits:

- Continuous monitoring
- Remote accessibility
- Real-time alert generation

Architecture of AI-Based Human–Animal Conflict System

A typical system consists of the following modules:

Data Acquisition Layer

Data sources include:

- CCTV Cameras
- Thermal Cameras
- Drones
- Motion Sensors
- GPS Collars

Processing Layer

Tasks include:

- Image preprocessing
- Feature extraction
- Animal detection
- Classification

AI Decision Layer

The AI model determines:

- Animal species

- Threat level
- Movement direction
- Probability of conflict

Alert and Response Layer
Actions:

- SMS alerts
- Mobile notifications
- Siren activation
- Forest department notification

Literature Review

Authors & Year	Technology Used	Application	Key Findings	Source
S. Jeevitha and V. Kumar (2020)	Image Processing, Sensors, Embedded Monitoring Systems	Animal Intrusion Detection in Agricultural Fields	Improved monitoring accuracy, reduced crop damage, and enabled remote farmer alerts.	*A Review of Animal Intrusion Detection System*, IJERT, Vol. 9, Issue 5, 2020. (IJERT)
Irene Nandutu, Marcellin Atemkeng, and Patrice Okouma (2022)	Machine Learning, Sensor Networks, AI-based Detection Systems	Wildlife–Vehicle Collision Prevention	Identified that ML-based systems reduce false detections and improve real-time animal detection accuracy.	*Sensors*, Vol. 22(7), 2022. (MDPI)
Ayan Paul (2025)	Artificial Intelligence, Computer Vision, CNN, YOLO, Edge Computing	Wildlife Monitoring and Animal Welfare	Demonstrated effective real-time animal monitoring, behavior analysis, and conservation management using AI-CV models.	*Computing and Artificial Intelligence*, Vol. 3(3), 2025. (ojs.acad-pub.com)
Irene Nandutu et al. (2022)	Deep Neural Networks, Computer Vision, Drone Imaging	Wildlife Tracking and Collision Risk Prediction	Improved prediction of wildlife movement and conflict hotspots using deep learning models.	*Mathematics*, Vol. 10(21), 2022. (MDPI)
Priya Sharma et al. (2020)	Deep Learning, CNN, PIR Sensors, Raspberry Pi	Crop Protection and Animal Identification	Achieved high animal classification accuracy and automated intrusion alerts for agricultural protection.	*International Journal of Progressive Research in Science and Engineering*, Vol. 1(4), 2020. (IJPRSE)

The reviewed studies indicate increasing adoption of deep learning and sensor-based systems for wildlife monitoring. However, challenges remain regarding deployment cost, environmental robustness, and model generalization.

Existing Detection Techniques
Sensor-Based Systems
Advantages:

- Low power consumption
- Simple deployment

Limitations:

- Limited detection range
- Environmental sensitivity

Camera-Based Systems
Advantages:

- High detection accuracy
- Visual verification

Limitations:

- Lighting dependency
- High computational requirements

Thermal Imaging Systems
Advantages:

- Night-time monitoring
- Weather resilience

Limitations:

- Expensive hardware

Drone-Based Monitoring
Advantages:

- Large area coverage
- Rapid surveillance

Limitations:

- Battery limitations
- Regulatory restrictions

Challenges in AI-Based Human–Animal Conflict Systems

Dataset Limitations

- Insufficient wildlife image datasets.
- Species imbalance.
- Seasonal variations.

Environmental Conditions

- Rain
- Fog
- Low illumination
- Dense vegetation

Hardware Constraints

- Power consumption
- Processing capability
- Network connectivity

False Alarms

- Incorrect detections may reduce trust in the system and increase operational costs.

Ethical and Privacy Issues

- Wildlife tracking ethics
- Data security concerns
- Responsible AI implementation

Future Research Directions

Edge AI Systems
Deployment of lightweight models on embedded devices for real-time processing.

Multimodal Sensor Fusion
Combining:

- Thermal cameras
- Acoustic sensors
- Vision systems
- GPS data

for improved accuracy.

Explainable AI (XAI)

- Improving transparency and trust in AI decisions.

Autonomous Monitoring Networks

- Using drones and robotic systems for continuous wildlife surveillance.

Predictive Analytics

- Forecasting animal movement patterns before conflicts occur.

Comparative Analysis

Technique	Accuracy	Cost	Real-Time Capability	Scalability
Sensor-Based	Medium	Low	High	High
Camera-Based	High	Medium	Medium	Medium
Thermal Imaging	Very High	High	High	Medium
Drone-Based	High	High	Medium	Low
AI + IoT Hybrid	Very High	Medium	High	High

The AI-IoT hybrid approach demonstrates the best balance between accuracy, scalability, and operational efficiency.

Conclusion

Human–animal conflict remains a major ecological and societal challenge. Advances in Artificial Intelligence, Machine Learning, Computer Vision, and IoT technologies have enabled intelligent systems capable of detecting, classifying, and tracking wildlife in real time. AI-based conflict management systems provide proactive monitoring and rapid response mechanisms that reduce damage to crops, property, and human life while supporting wildlife conservation efforts. Despite challenges related to datasets, environmental variability, and deployment costs, future developments in edge AI, sensor fusion, and explainable AI are expected to improve system reliability and adoption. AI-driven wildlife monitoring systems therefore represent a promising solution for achieving sustainable coexistence between humans and wildlife.

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