

Modern Techniques for The Identification and Monitoring of Insect Populations

Dr. Sunita Rawat¹

¹Department of Zoology, Government Degree College Gosaikheda Unnao

Received: 22 May 2026 Accepted & Reviewed: 25 May 2026, Published: 31 May 2026

Abstract

Insect identification is a crucial process and requires Specialisation. The use of technology, namely AI, Machine Learning, and drones, has been constantly increasing in entomological research. AI technologies, especially deep learning, computer vision, and neural networks, are being constantly used across various subsections of entomological research, such as insect identification, monitoring, detection, and classification, pest management, vector-borne disease control, and medical and forensic entomology. Use of drones (UAVs) and image-based monitoring systems improves the pollination studies, hence may be beneficial in agriculture. Adult and Life stages of Insects forms identification, Post Mortem Internal estimation, and Crime investigation can also be enhanced by using the latest AI technology. Thus, this paper reviews the use of modern technology, AI-driven approaches, and deep learning models in various entomological Applications.

Keywords: *Artificial Intelligence, Machine Learning, Insect Identification, Pest Management, Deep Learning Models.*

Introduction

Insects are the most diverse group on the earth. Insects inhabit all types of habitats, such as aerial, terrestrial, and aquatic. Recent data suggests that out of a million insect species, 80% remain to be discovered. Families like Coleoptera, Diptera, and Hymenoptera are comparatively less explored (Stork, 2018). Insects play a crucial role in the decomposition process of organic matter, improving soil fertility hence beneficial for energy flow in the food chain. They play a vital role in pollination, which is mandatory for Agriculture. Various insect species pose substantial harm to the food crops, and many act as vectors for harmful diseases as well. Thus, their identification and ecological study are very significant. Traditional methods of insect collection include hand picking, sweep net, aerial net, pitfall trap, light traps of different light sources, aspirator, aquatic dip net, etc (Imran et al., 2025). The traditional Insect population study is a time-consuming and labour-intensive method. Conventional insect monitoring practices and a smaller number of experts in entomological studies further delay the insect studies. New technological developments like Computer-based analysis, the internet, DNA studies, multi-sensor camera, etc might potentially solve the challenges in the insect identification processes.

INSECT IDENTIFICATION PROCESSES

TRADITIONAL METHODS

Traditionally, the identification and classification of insect species is based on their physical characteristics and physiology. Insect identification resources are available in the form of identification keys (Rashwin et al., 2023). Recent developments in Insect Identification methodologies have led to improvements in existing methods. With the help of DNA tools, many new insect species have been discovered.

MODERN TECHNOLOGY

Artificial Intelligence (AI) is a recent technology of computers, through which a system can develop the capability to perform different tasks that classically involve human intellect (Vishnoi et al., 2025). AI has

applications in various disciplines, including habitat studies, biodiversity assessment, pest control, sustainable solutions for farming, vector detection, and forensics. With the use of AI, the traditional methods of medico-legal investigations can be improved (Parmar and Rathod, 2021).

AI AND MACHINE LEARNING

AI integrated with smart traps, robotics, drones (UAVs), and an image-based monitoring system has helped to improve species identification and Real-time detection. Unmanned Aerial Vehicle (UAV) based models with Deep learning models such as YOLO (You Only Look Once) have revolutionized species identification (Chakrabarty et al., 2024). Insect images have been curated, annotated, augmented, and tested using 5 variants YOLOv5 viz, Nano, small, medium, large, and extra-large. Among all these variants, the YOLOv5 Large model was found to be the best for image accuracy and precision (Bjerge et al., 2023). Deep learning is considered to be the most reliable tool for fast identification of insects (Chakrabarty et al., 2024). YOLOv5 and Insectnet have played a vital role in insect morphological and ecological studies with an average precision of 96%. Deep learning models have been found very helpful in insect image analysis for plant disease-related studies (Haque et al., 2022). These are promising specially for the image analysis with complex backgrounds. Field conditions such as Noise interference and weather create hindrance during data collection and interpretation, affecting the accuracy and data quality. Object detection models are being trained to overcome the problems of complex backgrounds in real-time situations and for accurate data outcomes.

Given the small size and large diversity of insects, monitoring them proves to be a difficult task. But via Image Automation, this task can be accomplished easily. A customized time-lapse camera system has been developed to capture real-time images of insects. Image detection Models (YOLO) have been trained on the data sets using these images (Chakrabarty et al., 2024).

Analysis of insect images can be best achieved through deep-learning models. Captured images can be processed in real-time via deep learning models; these images can also be stored and analysed later on. For this task, the need for high-speed computational model surfaces, and YOLO emerges as the high-speed model for this (Bjerge et al., 2023). YOLO is a Unified Object Detection Architecture for Deep Neural Network. YOLOv5 was developed in the Python Programming Language, which can process and identify 30-100 image frames per second.

Convolutional Neural Networks (CNN) helps in the detection and classification of insect species, which increases the use of CNN in the field of technological studies (Kumar et al., 2025). Modern high-resolution cameras and CNN can be used to easily detect and classify insect images and videos. So far, most of the Automatic Insect Identification studies using CNN were carried out on dead species. But now the insects are being monitored in real conditions using cameras and computer automation. Researchers are working on the detection of similar species of insects in one large image. This model is also constructive in monitoring the seasonal abundance of insect species (Goswami, 2025).

Insects and their life stages were also detected using digital images through deep learning models (Ahsan et al., 2025). Egg, larva, Pupa, and Adult were identified and classified with the help of IP 102 Data set. Two Deep learning models ResNet50 and EfficientNetV2M, were tested for this study (Ahsan et al., 2025). Often times pest cannot be identified quickly for the protection of grains (Amrani et al., 2024). To reduce the environmental and safety hazards produced by the commonly used broad-spectrum insecticides for pest management, rapid and proper identification of insect species is important (Ahsan et al., 2025). Deep learning models can prove to be beneficial in cereal production and pest monitoring.

With the help of Electromagnetic and Laser Radar techniques based on the so-called Scheimpflug principle and a Continuous-Wave Laser, monitoring of large insect populations in the range of a few kilometres is possible (Brydegaard, 2015). This was possible due to remote sensing technology, which helped in observing insect wing-beat oscillations. Additionally, relative abundance, insect population, and behavioural study can be conducted. This technology can be very valuable in the field of pest identification, pest control, and disease vector control.

Conventionally, identification keys for insect identification were centred on their external morphology. But these identification keys may not be available for all morphologically and behaviourally differentiated members (caste) of the social insects. In some insect species, identification is based on the male genitalia; identification keys are available for the male genitalia but not the female (Karimzadeh and Sciarretta, 2022). Scarcity of specific keys for the larvae and pupae poses difficulties in species identification. Machine learning and Artificial intelligence are being used to overcome these challenges. There are images to classify egg, larva, pupa, and adults of 102 insect species in the IP 102 data set. These images are being analysed through Deep learning algorithms. (Ahsan et al., 2025).

CHALLENGES IN AUTOMATION

Although these models are profoundly advanced, they have yet to be developed for the identification of small insects in their natural surroundings. In training models along with insect identification, their background detection is equally important to avoid false data. Due to the high diversity of insects, there is an insufficient amount of data for all the insect classes. This makes it inconvenient for CNN to accurately detect unfamiliar insects (Bjerge et al., 2023).

CONCLUSION

Drones (UAVs) and image-based monitoring systems provide insights into insect behaviour and their movement patterns. AI-based upgraded predictions about insect distribution, abundance, and population studies in different habitats might be helpful for the agriculture industry. Smart traps and AI-enabled real-time insect pest identification could reduce the use of unnecessary pesticides and transform pest-management practices. Deep learning models may speed up the identification of insect life-cycle stages found on crime spots. Hence, these technological innovations could optimize the PMI estimation and detection of the culprit in cases of neglect and criminal investigations. A combination of Camera trapping, advanced remote sensing, and sound recording techniques may accelerate monitoring of insect biodiversity and Conservation strategies.

Deep learning models can be made more reliable by improving training data and using more advanced techniques. Emphasis should be placed on further enhancement of Machine learning and Artificial intelligence tools to improve their operational effectiveness in real-time and field conditions. In future research, the practical use of these models can be increased by focusing on testing their accuracy in various environmental conditions.

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