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ROLE OF ARTIFICIAL INTELLIGENCE IN REVOLUTIONIZING PEST MONITORING AND MANAGEMENT IN ENTOMOLOGY

Kishore S M[1*] and Arpitha S B[2]

[1]Ph.D Scholar, Entomology. Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences- Shivamogga-577204

[2]Ph.D, Department of Industrial Chemistry, Jnana Sahyadri, Kuvempu University, Shankaraghatta, Shivamogga-577204

**Corresponding Author Mail ID: kp464751@gmail.com*

Abstract

One of the most important branches of knowledge is entomology, which is a science that studies insects; which is important in agriculture, as these produce serious threats to agriculture health and can greatly reduce yield. Manually controlled pest management approaches hamper pest surveillance by integrating inefficient approaches that depend mostly on human judgement, which is prone to large errors. However, new changes in the pest management are being brought up by the artificial intelligence (AI) technologies of AI that brings in new solution to improve on pest detection identification as well as pest control. This article takes a look at ways through which artificial intelligence has impacted pest monitoring through machine learning algorithms, as well as computer vision systems. It covers the benefits of implementing automated systems, problems concerning quality and availability of data and the potential of AI in promoting climate smart agriculture. Finally, the work presented in this article proves that the orientation of entomology toward using AI as an effective tool carries an important transition to environmentally friendly approaches to pest management.

Introduction

Insects are part of global diversity and they are very essential in the food chain and in farming. Although insects are among the most diverse groups of animals, their numbers are declining dramatically, raising the need for practical measures of evaluation and control. Current methods of pest identification and management have predominantly involved use of labour and gross estimates, which are labour intensive and inaccurate. Where pest pressures are rising around the world's agricultural systems, new tools are needed to secure farmers' yields and methods. One sees that artificial intelligence (AI) has become as trends of scientific innovation in many disciplines, including entomology. In this paper we attempted to showcase the use of AI, researchers and practitioners can process massive amounts of data, recognize intricate relationships and derive conclusions and forecasts as to pest behaviour. This mainly aims at highlighting the disruption created by AI in pest tracking and how these technologies can help to aid in better pest control processes along with the connected difficulties.

Transformative Potential of AI in Pest Management

1. Automated Pest Detection

Perhaps, one of the leading and remarkable achievements in pest controlling is the invention of self-sensing pest control systems. These systems employ artificial intelligence and computer vision techniques to decode images which original sources include drones, cameras or smart phones. Thus, using convolutional neural networks (CNNs) these systems can identify pest species with a great level of accuracy and inform farmers or professional pest control services about possible pest invasion.

Automated pest detection systems offer several advantages:

a. **Rapid Identification:** AI algorithms are able to perform vast data analysis within a very short period of time thus giving a fast impression of pest existence. Such a rapid identification is important if intervention is to be done early enough to reduce crop damage and loss of yields.

b. **Reduced Labour:** Conventional routine survey to establish the presence or absence of a particular pest can be time-consuming, laborious, and expensive. It was more complex earlier but modern auto systems make the entire range monitored so effectively that it requires much less manpower now.

c. **Scalability:** Thanks to AI technologies, it is possible to inspect extensive territories of agriculture and develop preventive measures regarding pest infestations. This scalability is important for large scale farming undertakings because time is of essence once the invasion of pests has been realized.

d. **Increased Accuracy:** One of the major advantages of utilising AI in pest identification is that the false positive and false negatives results that created by these systems can be very low compared to employing simplistic approaches. This level of specification helps to improve on the reliability of pest management decisions.

2. Species Identification

Effective pest management also depends on species identification due to the fact that, different pests are likely to require different control measures. In this area, AI technologies are highly effective because of the ability to quickly and accurately determine an insect species. Predicting the ability of pest insects to form swarms can be achieved if machine learning is trained on large data sets of images and taxonomic data.

Benefits of AI in species identification include:

a. **Targeted Control Measures:** Correct identification of species enables farmers' application of appropriate control measures since they know the strategies which are appropriate depending on the life cycle of the pests.

b. **Biodiversity Monitoring:** Tools being used in these tools can help in assessments of biodiversity as the tools help in rapid estimation of insects in several habitats. This capability is helpful in conservation approaches and the study of the ecology.

c. **Citizen Science Engagement:** The citizen science members utilizing mobile applications that incorporate AI species identification to augment monitoring and contribution to entomological research datasets.

3. Decision Support Systems (DSS)

Another important ground-breaking innovation in pest management is the smart AI - powered decision support systems (DSS). These systems allow the consolidation of various inputs like weather conditions, disease or insect damage and population and can be beneficial to policy makers. Apart from identifying relationships between variables and the level of pest infestation at present, DSS enable farmers and pest control specialists to choose when and how to apply control measures based on the future patterns of pest outbreak.

Functionalities of DSS in pest management include:

Pest Forecasting: Some of the models provided by DSS for pest management allow determining pest outbreaks and its population density by history data, climate conditions and crops phenology. It also has ability to minimize impact of the pests by its foresight of the pest management techniques.

Risk Assessment: DSS evaluate the possibility of actual pest infestation or increased tendency of farmlands and other agricultural enterprises to

suffer economical loss, guiding the stakeholders to put priority on which and when to intervene.

Optimized Control Measures: DSS advise the correct time and frequency to use the pest control measures based on life-cycle of the pest and environmental factors. This optimization decreases the consumption of pesticides and thus; a reduction effect on the environment.

Real-Time Monitoring: Monitoring methods described herein enable DSS to generate alerts the moment pest thresholds are attained, thus enabling appropriate responses to new pest risks.

Challenges in Implementing AI in Entomology

While the potential of AI in pest monitoring and management is substantial, several challenges must be addressed to fully realize its benefits:

Data Quality and Accessibility: The effectiveness of AI algorithms relies heavily on the quality and representativeness of the training datasets. Many regions lack sufficient data on pest populations, leading to potential biases in AI predictions. Collecting comprehensive and diverse datasets is essential to enhance model accuracy and reliability.

Model Interpretability: AI models, particularly deep learning algorithms, can be complex and difficult to interpret. Understanding how these models arrive at their predictions is crucial for building trust among users and ensuring accountability in pest management decisions. Efforts to improve model transparency and interpretability are necessary for widespread adoption.

Integration with Traditional Practices: The integration of AI technologies into existing pest management practices may face resistance from traditional agricultural stakeholders. Education and training are vital to facilitate the adoption of AI tools and promote their benefits over conventional methods.

Future Outlook

AI has a bright prospect in agriculture especially for pest detection and control in the future. The projected opportunity of $65 billion in agriculture technology enhancements makes pest control measures a cause celebre of AI revolution. Key areas of focus include:

- **Continued Research and Development:** The constant evolution of new AI technologies is required to enhance the invented techniques and create new approaches specific to pest control problems.
- **Collaborative Efforts:** Synergy with researchers, farmers and technology developers of the system to be optimal for pest monitoring and management through AI. Drawing partnerships can help in converting knowledge and also enhancing data acquisition.
- **Sustainable Practices:** By scaling back pesticide use, improving efforts and decreasing costs of controls, AI technologies help in advancing sustainable practices at the agricultural level. There is a clear relation of the use of AI in pest management with other goals of environmental conservation and availability of food.

Conclusion:

Altogether, it is possible to talk about the revolutionary change of entomological investigations and pest control procedures due to integration of AI. Self-contained and capable of detection of pests, species identification and decision making make AI technologies a solution fit for pest management in agriculture. However, to ensure the reaping of these benefits, it is essential to overcome the following challenges; Being confronted with data quality, model interpretability for decision-making, integrating stakeholders for the model's application. This shows that as the AI technologies continue to advance by time and as these technologies become even more popular and within easy reach, major contributions in the improvement of pest management methodologies are still on the way. Through encouraging cooperation, funding for research and development and support of sustainable measures agriculture can greatly benefit from the utilisation of Artificial Intelligence to combat the demands of pest control and help

support a more efficient and sustainable Agricultural system. Pest management of the future is to apply Artificial Intelligence in the best way to develop technology that improves the yield of crops and reduces pest devastation to our crops and the environment.

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