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Critical Review: Machine Learning Algorithms for Reliability Assessment

Ms.J.Devika[1] ,Dr.P.Srimanchari[2]

[[1]Ph.D,Research Scholar, PG and Research Department of Computer Science, Erode arts and science College(Autonomous),Erode,Tamilnadu, India. Email: devikasaba@gmail.com]
[[2]Assiatant Professor of Computer Science,PG and Research Department Computer Science,Erode arts and science College(Autonomous), Erode,Tamilnadu,India. Email:srimanchari@gmail.com]

Abstract:

The organic waste is sustainable process for nature.vermicompost is a eco-friendly process of converting organic waste into nutrient-rich fertilizer. Ancient methods of vermicompost face some challenges. Regarding these issues, smart technologies containing Internet of Things (IoT) and Machine Learning (ML) have emerged. This survey paper enhances using Internet of Things and machine learning in datamining.To overcome the issues in the organic fertilizer. I review research from 2023 to 2025, analyzing advancements in sensor-based monitoring,AI-driven decision support, and automated control systems. This survey highlights the transformation potential of internet of things in achieving good fertilizer of vermicompost management.

Keywords: Vermicompost, Internet of Things, MachineLearning, Agriculture, Organic Waste Management, fertilizer.

Introduction:

Soil fertility and health are fundamental to the success of agricultural systems, influencing health of the plant, yield of crops and sustainability of ecosystem. As the global population continues to rise, the demand for food production intensifies, placing increasing pressure on agricultural lands[17].Vermicomposting is defined as the process of stabiliztion and process of biodegradation in organic materials, facilitated by the collaborative efforts of earthworms and mesophilic microorganisms[18].To integrate the sensors embedded IoT and Machine Learning that offers a smart methodology of vermicompsost practices in revolutionary shift. IoT-based systems enable real-time monitoring of critical environment.This paper presents a detailed survey of recent smarter advance vermicomposting and how it play the contribution of agriculture field sustainability.

Literature Review

The beneficial microorganisms in vermicompost can suppress harmful pathogens, reducing the soilborne diseases and developing plant's health.Better Crop Quality: Vermicompost increases the quantity of crops and quality also, with taste, color, and nutritional content, it improve the nutrient.Different species of earthworms are better suited for different environments and composting systems. The most commonly used earthworm species in vermiculture are epigeic, endogeic, and anecic earthworms[1].The problem is framed as a multiclass classification problem where each class represents a different stage of the vermicompost,The SVM model is a machine learning technique used in statistical learning theory, it reduces the upper bound of the model generalization error while minimizing error.which improves the venerability of the model. The core concept behind SVM would be to use the kernel transform to accurately classify low-dimensional, linearly indivisible problems in high-order space[2].The continuous process is very effective for treating large quantities of waste, requiring less labour to operate but could require some technical maintainable. In all vermicomposting technology is far better in waste valorisation and management than the traditional composting method for waste treatment due to its efficiency and environmental friendliness in the waste bioconversion process. This technology has significant values and environmental consequences that range from decreased emission of greenhouse gases, minimized odour, increased enzyme activities, quick biomass recycling, vermiculture production to efficient operation during coldseason/weather[3].Kitchen waste materials are rich in nutrients and contain significant amounts of carbohydrates, lipids, proteins, and other organic compounds. These components create a favorable environment that supports the growth and proliferation of diverse microbial population develop an automated portable vermicomposting bin using Raspberry Pi, sensors, LED grow light, automatic irrigation system, temperature sensor and soil moisture sensor. The overall module should be a mixed combination of agriculture with technology. This automated portable bin will provide convenience and comfort to the user by sensing and controlling the parameter of the bin using a data logging system though which wecan control it effectively[4].

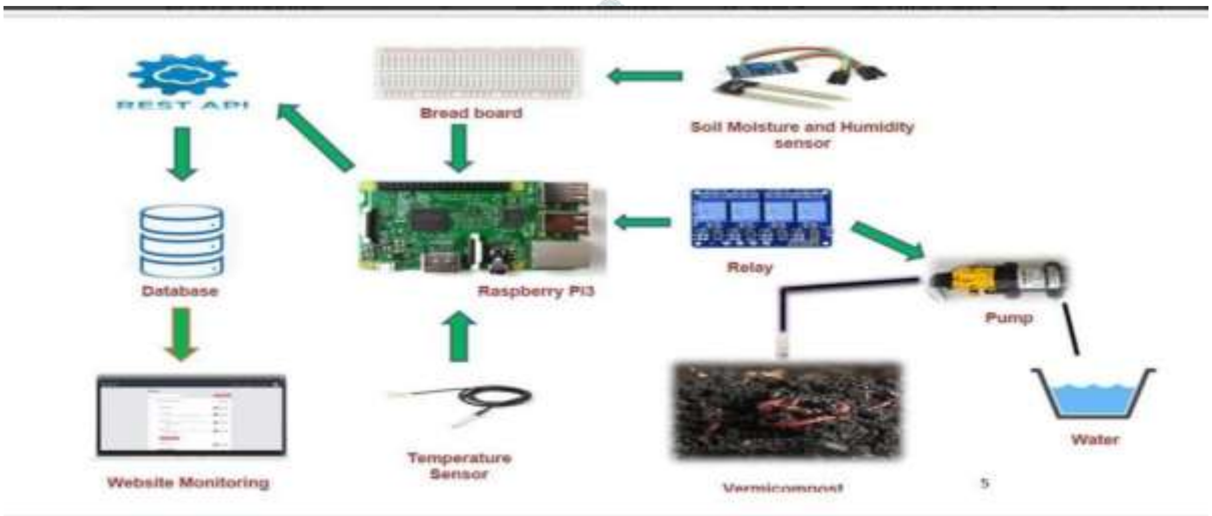

Figure:IoT based Vermicomposting Bin System[4].

As the antenna travels through the GI tract, it experiences detuning in its impedance response due to the varying EM properties of the GI tissues,e three types of antennas exhibit favorable characteristics for most of the cases, indicating their potential suitability as biosensors in the GI tract[5].The algorithms used in the PlantVillage dataset for the classification category, specifically for RGB images, achieve performance accuracy of up to 99% . In the field of computer vision, the decision-making process for selecting appropriate methodologies ,CNN is the most common neural network architecture used throughout the studies. There are also some works dealing with classifying diseases that use SVM, ANN, RF, KNN, and MLP algorithms. Regarding the method that each study targets, classification is the clear winner compared to object detection. Different metrics have been employed in the literature, with accuracy, F1-score, precision, and recall being among the most commonly used one[6].Gallium arsenide is a semiconductor material known for its high efficiency and performance, making it an attractive choice for various applications, including waste management systems.The gallium arsenide (GaAs) processing schema is selected for waste composition prediction because of its stability in processing a variety of waste materials and great efficiency in managing intricate separations. GaAs is especially useful in the vermicomposting process for separating organic and inorganic compounds because of its exceptional chemical qualities, which enable accurate waste component separation. This schema helps the neural network detect minute changes in waste composition, which further improves the model's forecast accuracy[7].AHA-LEACH is a proposed method for addressing the aforementioned issues with LEACH and reducing missing data sent from smart bins into disposal centers. Therefore, the transmission has been changed from smart bins (nodes) to CH, which In the updated system, data from smart bins is first sent to a Cluster Head (CH), which then forwards the aggregated information to the disposal center (DC), improving overall transmission efficiency. The proposed AHA-LEACH algorithm is designed to overcome existing research gaps by using the Artificial Humming Algorithm to create optimized clusters of smart bin nodes[8].IoT sensor technology uses RFID tags andand can be placed anywhere,IoT sensors are extremely useful where continuous real-time monitoring is required,source, like Dam, lake, river to treatment facility (WTP) to storage reservoirs (ESR/ GSR) further to consumer taps, these sensors can be installed to monitor water quality every now and then. These sensors are connected to small dedicated microcontrollers which process data partially and send to centralized server. These sensors are customized to measure temperature,pH,turbidity,dissolved,Oxygen levels of gases (Chlorine/ Ammonia), metals and minerals or traces of pathogens and microplastics[9].

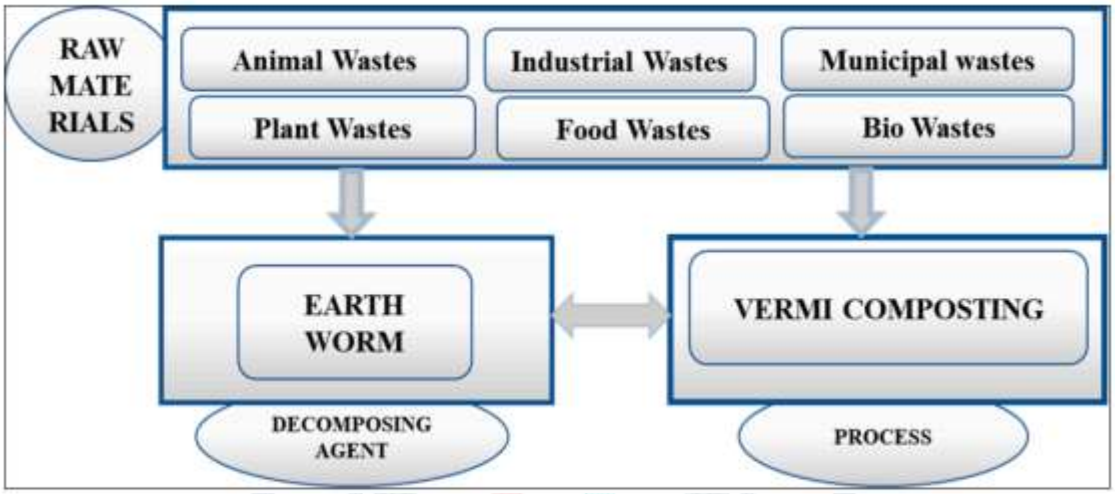

Figure 1. Vermicomposting process and its relative components[7]

EcoGold was developed to improve the success rate of the vermicomposting process by monitoring the temperature and moisture in real time to assist in any manual intervention when required. The proposed automated monitoring system is built with the help of sensors and wireless network to transmit live data of the compost from compost bin to the monitoring system on the cloud server. This allows for off-site remote monitoring of the compost thereby reducing manual work[10]. Hawaii Kauai Island Microgrid: Kauai is an island in Hawaii that has developed a microgrid based on renewable energy sources.This microgrid integrates solar energy and energy storage systems to meet the island's energy needs. The sensors used in the microgrid play a critical role in monitoring the energy production from solar panels and managing the energy storage systems.the balance between energy production and demand has been continuously optimized. As a result, Kauai Island has reduced its energy costs and significantly decreased its use of fossil fuels. Brooklyn Microgrid: The Brooklyn Microgrid is a microgrid established in New York with the aim of increasing energy independence. This system enables energy trading among homes equipped with solar panels. Sensors monitor the energy production and consumption of each home to manage this trade. This project stands out as an example of using sensors to turn energy consumers into producers and support energy exchanges within local communities. The sensor data has ensured the system remains sustainable and economical by balancing energy supply and demand microgrid[11]. The emergence of Internet of Things (IoT) and sensor technologies presents a transformative solution, enabling real-time data acquisition, automated monitoring, and intelligent alerts. However, the integration of these technologies is hindered by several challenges:• High Deployment Costs: Establishing IoT-based monitoring systems demands substantial financial investment, which may not be workable for all regions.Energy Consumption and Maintenance: Many IoT sensors require consistent power supply and regular servicing, posing sustainability concerns. • Data Security and Privacy Risks: The extensive environmental data collected by IoT systems raises cybersecurity vulnerabilities and potential data misuse.

• Scalability and Compatibility Issues: Merging IoT solutions with existing environmental frameworks and infrastructures remains a complex task[12].this is the first effort to integrate satellite RS and DL to quantify agricultural activity. Furthermore, the study includes a formal accuracy assessment of several computer vision CD models implemented in agricultural systems, providing a quantitative baseline to monitor the spatialtemporal dynamics of the diversity of management practices.For each agricultural pixel *p*, an intensification score *Ip* is computed as the normalized frequency of detected changes

$$I_p = \frac{1}{C_{\max}} \sum_{t=1}^{T} C_{p,t}$$

where *Cp,t* ∈ *{*0, 1*}* denotes the binary outcome of the CD at time *t* for pixel *p* (1 for a change event, 0 otherwise), *T* is the total number of observation periods, and *C*max is the theoretical maximum number of detectable events.*C*max is defined as the 0.99th percentile of the distribution of event counts across all agricultural pixels [13].Logistic Regression was a great baseline model since it is simple and interpretable, the relationship between features and the target variable can easily be understood. Among these, Random Forest is renowned for its resistance to overfitting and handling high-dimensional feature spaces, hence suitable for high-dimensional data. Support Vector Machine, on the other hand, is highly predictive and thus efficient in capturing those minute patterns that are very relevant in the subtle domain of mental health. Model selection depends not only on dataset characteristics, such as size and dimensionality, or type structured versus unstructured but also on the nature of the prediction to be made.Cross-validation techniques, such as k-fold cross-validation, were employed in assessing the performance of the model to enhance its robustness. It was based on partitioning the training data into k subsets and running the model k times, each time with a different subset for validation, to avoid overfitting[14].Mamba cross-fusion module and the semi-supervised mechanism in extracting robust multi-modal features.the Cross Mamba Encoder enhances multi-modal fusion, while the semi-supervised mechanism improves the utilization of labeled and unlabeled data, leading to a cumulative improvement in classification accuracy proposed a fully supervised generative spectral space classifier (DGSSC) to solve the problem of unbalanced hyperspectral image classification[15].*distributed learning* is used with the same meaning as learning from distributed data. The following subsections explore different distributed learning architectures such as Federated Learning (FL), Split Learning (SL), Ensemble Learning (EL), Decentralized Learning (DecL)heoretical landscape concerning machine learning evolution, first in relation to Privacy Preserving Machine Learning (PPML) and secondly in the field of Privacy Enhancing Technologies (PETs). The evolution of ML and DL applied to centralized data has been carefully analyzed to move on to the application of these models with architectures acting on distributed data. In this sense, different state-of-the-art approaches have been presented, from well-known federated learning to split learning, gossip learning, and other decentralized architectures[16]. Vermicompost will be prepared in a plastic bag,collected the dried biomass and chonped them , mixed the chopped dry material with cow dung in a 50:50 ratio and will be kept them aside for 15-20 days for partial decomposition , added a thin layer of soil/sand (2-3 inches) at the bottom of tank, released the earthworms in the tank and covered the mixture with green leaves ,monitoring the bin and added egg shells,watered regularly to maintain moisture[19].Due to the absence of global time synchronization during data collection, misalignment remained between the beam-crossing sensor records and the CCTV camera measurements. To address this issue, an automated technique was developed to estimate the temporal offset between the two data sources. The approach employs time-domain cross-correlation between paired signals. One signal corresponds to object-passage events captured by a physical infrared (IR) beam-crossing sensor, while the other is derived from the video analytics module. In the video-based signal, object crossings are identified by detecting intersections between tracked object trajectories and a predefined polygon that approximates the sensing region of a virtual beam-crossing sensor, constructed using spatial data analysis frameworks [20].

Methodology:

The methodology of this survey involves systematic review and reasoning of literature between 2023 and 2025:Databases: IEEE, Springer, ACM, ScienceDirect, Google Scholar.

Keywords: Vermicomposting, Sensors, IoT, Machine Learning, Smart Agriculture.

Inclusion Criteria: Peer-reviewed works (2023–2025) related to Internet Of things with Machine Learning in vermicomposting. Exception Criteria: Works on traditional composting without Machine

Learning with Internet of Things.

Categorization: Studies grouped into detection, predictive modeling, high technology and optimization.

Comparative Analysis & Discussion:

Across the reviewed literature, IoT-based sensing improved environmental stability, while ML models enhanced prediction quality for compost. AI-driven compost monitoring enabled active involvement, reducing value rates. Renewable energy integration lowered costs, and ensured traceability. Edge AI and Associated learning reduced dependence storage of data in centralized. Challenges remain in affordability, data complexity, and scalability in rural settings.

Future Directions:

- IoT embedded systems to enhance the quality of vermicompost traceability.
- Decentralized processing commented by Edge AI and learning process.
- For rural adoption easy handle by low price sensors.
- For sustainability it must be enhance with circular economy model.

Conclusion:

This survey demonstrates the potential transformative of Machine learning and Internet of Things in vermicomposting. Reviewed works highlight improvements in compost maturity, worm health, and environmental sustainability. With the inclusion of edge AI, and biosensors and future vermicomposting systems become secure, efficient and scalable to global property agriculture.

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