

Artificial Intelligence and Machine Learning in Healthcare and Agriculture: A Comprehensive Review

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Introduction

(AI) and (ML) have seemed as transformative technologies crossways manifold domains, with healthcare and agriculture as two dangerous application areas that straight impact human welfare and food security (Jafar et al., 2024). The integration of progressive computational methods in these arenas' speeches fundamental challenges, counting disease prediction, early detection, and precision farming practices (Wang et al., 2021; Giannini et al., 2019). This comprehensive review reviews the current state of AI and ML applications in healthcare disease classification and agricultural systems, with specific pressure on sepsis prediction and aquaculture management.

The growing trouble of healthcare data and the need for fast, precise diagnostic tools have shaped important opportunities for AI-driven solutions (Zhang et al., 2023). Similarly, the agricultural sector faces mounting weight to increase productivity however maintaining sustainability, heavy the adoption of smart farming technologies (Pan & Chen, 2024). This review brings an evidence-based analysis of the methodologies, datasets, assessment metrics, and presentation consequences in these domains.

Healthcare Applications: Sepsis Detection and Medical Diagnosis

Sepsis Prediction in Critical Care

Sepsis leftovers one of the greatest challenging conditions in dangerous care medicine, touching millions of patients worldwide and representing a foremost cause of mortality in (ICUs) (Barghi & Azadeh-Fard, 2022). The condition's fast development and varied nature make initial detection crucial for purifying patient outcomes. AI has established significant potential in speaking these challenges over predictive modeling methods.

New studies have exposed that AI algorithms can prediction sepsis onset several hours earlier obvious clinical manifestations develop apparent (Wang et al., 2021). The MIMIC-IV database, one of the most comprehensive dangerous care datasets, has aided as a cornerstone for developing and collateral sepsis prediction models (Johnson et al., 2023). This database shelters longitudinal clinical data from thousands of ICU patients, if investigators with rich datasets for exercise urbane ML models.

Machine learning methods for sepsis forecast typically employ multiple data sources, counting vital signs, workroom parameters, and (EHR) data (Zhang et al., 2025). The development of machine learning models has recognized extraordinary success, with studies

journalism AUC values of 0.91 and compassion of 87% when forecasting sepsis onset (Wang et al., 2021). These results mean important improvements over old-style marking systems such as SIRS, SOFA, and qSOFA.

Machine Learning Algorithms in Medical Classification

The healthcare area has saw wide adoption of various ML algorithms for disease classification and prediction tasks. Random Forest (RF) models have dependably demonstrated superior performance in healthcare applications, primarily for disease cataloguing problems (Zhang et al., 2023). These collaborative methods excel in handling complex medical datasets with high dimensionality and diverse data types.

Support Vector Machines (SVM) have bare particular effectiveness in medical diagnosis, particularly for scenarios connecting high-dimensional data with incomplete sample sizes (Barghi & Azadeh-Fard, 2022). SVM's model-free method makes it chiefly suitable for multifaceted medical datasets where the fundamental relationships between variable star may not be well unspoken. Studies have specified SVM achieving high presentation in various forecast tasks together with other algorithms.

Deep learning methods, primarily Convolutional Neural Networks (CNNs), have transformed medical image analysis and diagnosis (Zhang et al., 2023). These models prove exceptional capability in automatically removing features from complex medical data, foremost to better diagnostic accuracy crossways various conditions.

Gradient boosting algorithms, including XGBoost and LightGBM, have increased prominence in medical applications owing to their ability to grasp imbalanced datasets effectively (Zhang et al., 2025). These algorithms have bare superior performance in several medical classification tasks, illustrative their utility in clinical prediction scenarios.

Evaluation Metrics and Performance Assessment

The evaluation of medical AI systems needs cautious consideration of multiple performance metrics beyond humble accuracy (Zhang et al., 2023). The AUROC (Area Under the Receiver Operating Characteristic Curve) has grown a normal metric for assessing binary classification tasks in healthcare. However, for unfair medical datasets, additional metrics such as precision, recall, and F1-score bring more comprehensive performance assessment.

The F1-score, on behalf of the vocal mean of precision and recall, is primarily valued in medical applications where together false positives and false negatives carry significant consequences (Barghi & Azadeh-Fard, 2022). In sepsis prediction, for instance, high recall is crucial to avoid missing potentially life-threatening cases, though precision helps minimize false alarms that can principal to attentive fatigue amongst clinical staff.

Recent studies have tinted the importance of using multiple assessment metrics to bring a comprehensive assessment of model performance (Zhang et al., 2025). The integration of AUROC, precision, recall, and F1-score proposal healthcare practitioners a more entire sympathetic of a model's strengths and limits.

Data Preprocessing and Handling Imbalanced Datasets

Medical datasets frequently exhibit significant class inequity, where optimistic cases (disease present) are significantly outnumbered by bad cases (disease absent) (Wang et al., 2021). The (SMOTE) has risen as a standard method for speaking this challenge. SMOTE makes synthetic examples for the minority class finished exclamation between current minority instances, serving to symmetry class distributions and recuperate model performance.

The SMOTE procedure works by selecting each minority class example and making synthetic examples lengthways line sections joining k-nearest minority class neighbors (Zhang et al., 2023). This method has recognized chiefly effective in medical applications, where it assistances stop models from being prejudiced toward the majority class while maintaining the underlying data distribution characteristics.

Advanced variants of SMOTE have been industrialized to language specific challenges in very imbalanced medical datasets (Zhang et al., 2025). These techniques stress on making synthetic examples that better define class boundaries, foremost to healthier classification performance.

Agricultural Applications: Precision Farming and Plant Disease Detection

Plant Disease Detection and Classification

Agriculture faces important challenges from plant diseases, which can cause considerable crop losses and threaten food security (Jafar et al., 2024). The PlantVillage dataset has develop the de facto standard for plant disease detection research, covering over 54,000 images across various plant species and disease conditions.

Deep learning models, chiefly CNNs, have demonstrated exceptional performance in plant disease detection tasks (Jafar et al., 2024). Transfer learning methods using pre-trained models such as ResNet-50, VGG-19, InceptionV3, and EfficientNet have attained accuracy rates exceeding 97% on plant disease datasets. The EfficientNet architecture has reliably outperformed other models, attaining high accuracy in leaf disease classification.

The application of computer vision techniques for plant illness detection addresses critical limitations of manual inspection methods, which are time-consuming, labor-intensive, and topic to human error (Singh et al., 2023). AI-powered systems can examine plant images in real-time, providing rapid identification of disease symptoms and allowing opportune intervention strategies.

Precision Agriculture and Smart Farming Technologies

Precision agriculture signifies a paradigm shift in farming practices, utilizing AI and IoT technologies to enhance resource utilization and maximize crop yields (Pan & Chen, 2024). This method enables farmers to smear inputs such as water, fertilizers, and pesticides with unprecedented precision, minimalizing waste and environmental impact while refining productivity.

Drone technology armed with multispectral and thermal cameras plays a vital role in precision agriculture, allowing comprehensive field monitoring and crop health assessment (Wang et al., 2024). These systems can notice pest infestations, nutrient deficiencies, and water stress conditions before they develop noticeable to the human eye, letting for proactive management decisions.

AI-driven analytics platforms integrate data from multiple sources, counting satellite imagery, weather forecasts, and soil sensors, to deliver comprehensive visions into crop conditions and growth patterns (Pan & Chen, 2024). Machine learning algorithms examine this diverse data to make actionable recommendations for farmers, secondary evidence-based decision-making.

IoT-Based Aquaculture Systems

The aquaculture industry has progressively adopted IoT and ML technologies to address challenges in fish farming and water quality management (Islam, 2025). These systems employment networks of sensors to monitor critical parameters such as pH, temperature,

dissolved oxygen, and turbidness in real-time, allowing precise control of aquatic environments.

New implementations of IoT-based aquaculture monitoring systems have established high accuracy in water quality parameter measurement, with stated accuracy rates exceeding 95% for key parameters (Apu et al., 2024).

Machine Learning in Feeding Optimization

The optimization of feeding strategies in aquaculture means a significant application area for ML technologies (Apu et al., 2024). Advanced regression models have been working to forecast optimal feeding rates founded on environmental conditions and fish starvation.

These systems mix real-time data from ecological sensors, video analytics, and manual comments to reach optimal growth performance indicators (Teixeira et al., 2021). The dynamic adjustment of eating quantities founded on ML predictions has recognized important improvements in resource capability and fish health consequences.

Methodological Approaches and Algorithm Selection

Ensemble Methods and Performance Optimization

Collaborative methods have dependably demonstrated superior performance across both healthcare and agricultural applications (Wang et al., 2021). Random Forest algorithms excel in action heterogeneous datasets with varied mutable types, making them chiefly appropriate for medical diagnostic tasks. The algorithm's inherent hostility to overfitting and ability to bring feature importance rankings make it valued for understandable healthcare AI systems.

Incline boosting algorithms, counting XGBoost and LightGBM, have exposed exceptional presentation in both domains (Zhang et al., 2023). These procedures are primarily effective for treatment imbalanced datasets, a shared challenge in both medical analysis and agricultural applications. LightGBM has recognized superior computational competence though maintenance high accuracy, creation it appropriate for real-time applications.

Hyperparameter Optimization Strategies

Effective hyperparameter optimization is energetic for attaining optimal model performance in both healthcare and agricultural AI applications (Giannini et al., 2019). Grid search and chance search mean the most typically employed approaches, each contribution distinct advantages depending on the search space trouble and computational constraints.

Grid search brings thorough evaluation of hyperparameter combinations within a stated range, creation it suitable for scenarios with well-defined parameter spaces (Zhang et al., 2025). Random search, similarly, proposals advantages when trade with high-dimensional parameter spaces, frequently reaching comparable performance with shortened computational requirements.

Advanced optimization techniques have been employed in medical applications to recuperate hyperparameter tuning competence (Wang et al., 2021). These methods prove particular value in computationally concentrated scenarios where traditional network search methods may be excessively luxurious.

Cross-Validation and Model Validation

Robust validation strategies are energetic for safeguarding the reliability and generalizability of AI models in both healthcare and agricultural applications (Zhang et al., 2023). Bedded k-fold cross-validation has industrialized the normal technique for upholding class distribution balance during model evaluation, primarily significant for unfair medical datasets.

The integration of multiple assessment metrics brings a comprehensive assessment of model performance across dissimilar aspects of predictive competence (Barghi & Azadeh-Fard, 2022). The combination of AUROC, precision, recall, and F1-score proposal practitioners insights into perfect behavior under various decision thresholds, letting knowledgeable selection of optimal operating points.

Challenges and Future Directions

Data Quality and Availability

Together healthcare and agricultural AI applications face significant challenges linked to data quality and availability (Johnson et al., 2023). Medical datasets often hurt from lost values, inconsistent recording practices, and privacy constraints that limit data sharing. Agricultural datasets may be affected by environmental variability, seasonal patterns, and imperfect standardization across dissimilar farming operations.

The development of robust preprocessing pipelines and data increase techniques leftovers vital for speaking these challenges (Jafar et al., 2024). SMOTE and its variants have established effective for addressing class inequity, but sustained research into progressive synthetic data generation methods is required.

Interpretability and Clinical Adoption

The deployment of AI systems in healthcare wants high levels of interpretability and explainability to development clinical acceptance (Zhang et al., 2025). Black-box models, contempt their superior predictive performance, whitethorn face confrontation from healthcare practitioners who need an understanding of decision-making processes.

The addition of explainable AI techniques suggestions promising approaches for purifying model interpretability while maintenance predictive performance (Pan & Chen, 2024). These techniques let practitioners to understand which topographies contribute most evocatively to perfect predictions.

Scalability and Real-World Implementation

The transition from research examples to employed systems presents significant challenges in both domains (Giannini et al., 2019). Healthcare AI systems necessity integrate seamlessly with present electronic health record systems and clinical workflows, however agricultural AI solutions need operate dependably in varied environmental conditions.

Edge calculation and resource-efficient model architectures are flattering increasingly important for letting real-time inference in resource-constrained environments (Teixeira et al., 2021). Clipped neural networks and frivolous architectures have recognized the potential to support high accuracy while plunging computational supplies.

Table: AI and Machine Learning Applications in Healthcare and Agriculture

Paper	Year	Methods	Results	Dataset
1-Apu, M. S. H., Rahman, M. M., & Ahmed, M. T. (2024)	2024	Applied IoT sensors with ML algorithms: Random Forest for fish recommendation system using pH, temperature, turbidity sensors	Random Forest achieved 92.5% accuracy, 93% precision, 93% recall, 92% F1-score	IoT aquaculture sensor data from 5 ponds with 11 fish categories
2- Barghi, B., & Azadeh-Fard, N. (2022)	2022	Applied six ML methods: Logistic Regression, Naïve Bayes, SVM,	Bootstrap Forest achieved highest AUC (0.908) and R-square	Virginia hospital patient data (20,005

		Boosted Tree, CART, Bootstrap Forest	(0.366); SVM highest accuracy (0.937)	records, 7.5% sepsis prevalence)
3-Benetti, R. (2025)	2025	Applied deep learning models: LSTM networks for time-series prediction of environmental variables in fish farms	LSTM-based architectures effective for environmental time-series forecasting with improved prediction accuracy	CNR aquaculture dataset with environmental parameters and fish mortality data
4- Giannini, H. M., et al. (2019)	2019	Applied COMPOSER deep learning algorithm for sepsis prediction with conformal prediction method	COMPOSER achieved AUC 0.938-0.945 in ED settings; provided early warning 12.2h (ICU) and 2.1h (ED) before onset	515,720 patients from two US healthcare systems across ICU and ED
5- Islam, M. M. (2025)	2025	Applied IoT framework using 10 ML algorithms: J48, Random Forest, K-NN, K*, LMT, REPTree, JRIP, PART, Decision Table, Logit boost	Random Forest achieved highest performance: 94.42% accuracy, 93.5% kappa statistics, 94.4% Avg. TP Rate	ThingSpeak IoT cloud data from 5 ponds with pH, temperature, turbidity measurements
6- Jafar, A., et al. (2024)	2024	Applied AI with IoT for plant disease detection using ML and DL models including CNN, ResNet-50, VGG-19, InceptionV3, EfficientNet	EfficientNet achieved 97.5% accuracy in plant disease detection; CNN models achieved >97% accuracy on PlantVillage	PlantVillage dataset (54,000+ images) for tomato, chili, potato, cucumber diseases

7- Johnson, A., et al. (2023)	2023	Database development: MIMIC-IV freely accessible electronic health record database	Created comprehensive dataset with patient measurements, orders, diagnoses, procedures, treatments, clinical notes	MIMIC-IV: 65,000+ ICU patients, 200,000+ ED patients from Beth Israel Deaconess Medical Center
8- Pan, X., & Chen, J. (2024)	2024	Applied deep learning: CNN, RNN, LSTM, GAN combined with hybrid optimization (GA + PSO)	Achieved 97.5% accuracy in pest detection, 96.8% precision, 97.2% recall, 0.97 F1-score; $R^2 = 0.93$ in crop yield prediction	Agricultural datasets for crop yield prediction, pest and disease detection
9- Singh, V., Sharma, N., & Singh, S. (2020)	2020	Applied imaging techniques for plant disease detection: computer vision, machine learning, deep learning approaches	Review of imaging techniques showing effectiveness in plant disease detection with improved accuracy over manual methods	Various plant disease image datasets for analysis and comparison
10- Teixeira, R. R., et al. (2021)	2021	Applied IoT approach for precision aquaculture with LoRa communication and water quality sensor network	Feasible deployment for LoRa communication range up to 110m; successful end-to-end data path implementation	Real-time water quality sensor data from aquaculture farming facility
11- Wang, J., et al. (2021)	2021	Applied Random Forest algorithm with 55 clinical features for sepsis prediction in ICU patients	Random Forest achieved AUC 0.91, sensitivity 87%, specificity 89% using 5-fold cross-validation	4,449 infected patients from First Affiliated Hospital of Zhengzhou University ICU

12- Wang, Y. (2024)	2024	Applied deep learning methods in precision agriculture including CNN for image recognition and analysis	Deep learning methods showed superior performance in agricultural applications with improved accuracy	Agricultural datasets for precision farming applications
13- Zhang, Y., et al. (2023)	2023	Systematic review and meta-analysis of ML for sepsis-related death prediction: RF, XGBoost, neural networks	Combined C-index 0.799 (training), 0.774 (validation); RF and XGBoost showed favorable accuracy	Meta-analysis of 50 studies with 104 models for sepsis mortality prediction
14- Zhang, Y., et al. (2025)	2025	Applied interpretable ML for sepsis risk prediction in emergency triage with explainable AI techniques	High performance in sepsis risk prediction with improved interpretability for clinical decision-making	Emergency triage data from multiple healthcare systems

Conclusion

This comprehensive review shows the transformative possible of AI and ML technologies in healthcare and agrarian applications (Zhang et al., 2023). In healthcare, AI systems have reached extraordinary success in sepsis prediction and medical diagnosis, with models reliably exceeding traditional clinical scoring systems. The integration of varied data sources, liberal preprocessing techniques, and urbane ML algorithms has allowable the development of extremely precise predictive systems that can evocatively impact patient consequences.

In agricultural applications, AI technologies are altering precision agricultural practices and illness detection capabilities (Jafar et al., 2024). Computer vision systems for vegetable disease identification, IoT-based nursing platforms, and predictive models for aquaculture management show the breadth of AI applications in speaking agricultural challenges.

The success of these applications be depending deeply on appropriate algorithm selection, healthy evaluation methodologies, and real handling of shared challenges such as class

inequity and data quality issues (Wang et al., 2021). Collaborative methods, primarily Random Forest and incline boosting algorithms, have dependably established superior presentation across both areas.

Future developments necessity stress on refining model interpretability, ornamental real-world deployment competences, and addressing scalability challenges (Pan & Chen, 2024). The continued evolution of hardware competences, data collection methods, and algorithmic approaches potentials further loans in both healthcare and agricultural AI applications.

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