International Journal of
Power Electronics Controllers and Converters

ISSN: 2456-1614
Volume 10, Issue 1, 2024
DOI (Journal): 10.37628/IJPECC

https://journalspub.com/?indexing_body=ijpecc

Review IJPECC

Unlocking Insights, Optimizing Processes: A Review of Machine Learning in Action

Sneha Raj M.P.[1,*], Farsana Muhammed[2]

Abstract

Machine learning (ML) has become a disruptive technology with applications in many different fields and sectors. Machine learning techniques are transforming the way data is examined, patterns are found, and decisions are made in a variety of industries, including healthcare, finance, manufacturing, and transportation. ML is improving drug discovery, treatment strategies, and diagnostics in the healthcare industry. In the financial sector, this means maximizing risk mitigation, credit scoring, and fraud detection. Machine learning (ML) enables process optimization, quality control, and predictive maintenance in manufacturing. ML is useful for transportation in the areas of route planning, autonomous vehicles, and logistics. These uses highlight machine learning's ability to increase productivity, cut expenses, and spur creativity, making it a vital component of contemporary technological developments. Machine learning (ML) is a rapidly evolving field with immense potential to revolutionize various aspects of our lives. This review explores the diverse applications of ML across various sectors like finance, health care, transportation, autonomous industries, manufacturing, data security and analyzing its impact and future potential. It also discusses ML's role in industrial sensing and control, addressing challenges and offering practical perspectives on process monitoring, fault detection, and control optimization. The paper gives an idea about the machine learning techniques performed in various applications and can analyze that which of the techniques are suitable for each application. This comprehensive review provides a valuable resource for researchers, practitioners, and policymakers interested in understanding the transformative power of ML across diverse industries.

Keywords: Machine learning (ML), applications, optimization, unlocking, application programming interface, support vector regression

***Author for Correspondence**
Sneha Raj M.P.
E-mail: 23514@tkmce.ac.in

[1]M. Tech Scholar, Department of Electrical & Electronics Engineering, TKM College of Engineering, Kollam, Kerala, India
[2]Assistant Professor, Department of Electrical & Electronics Engineering, TKM College of Engineering, Kollam, Kerala, India

Received Date: May 15, 2024
Accepted Date: June 08, 2024
Published Date: June 20, 2024

Citation: Sneha Raj M.P., Farsana Muhammed. Unlocking Insights, Optimizing Processes: A Review of Machine Learning in Action. International Journal of Power Electronics Controllers and Converters. 2024; 10(1): 14–22p.

INTRODUCTION

Machine learning (ML) has emerged as a transformative technology with applications across a wide range of industries and domains. From healthcare and finance to manufacturing, transportation, and beyond, ML techniques are revolutionizing how data is analyzed, patterns are discovered, and decisions are made. In healthcare, ML is enhancing diagnostics, treatment plans, and drug discovery. In finance, it's optimizing fraud detection, credit scoring, and risk management. In manufacturing, ML is driving predictive maintenance, quality control, and process optimization. Transportation benefits from ML in logistics, autonomous vehicles, and route

© JournalsPub 2024. All Rights Reserved

optimization. These applications underscore ML's potential to improve efficiency, reduce costs, and drive innovation, making it a cornerstone of modern technological advancements.

The study [1] employs the use of machine learning in healthcare, specifically in the context of outcome prediction models developed using data extracted from electronic health records and various machine learning (ML) techniques, including Fourier and wavelet transforms, time domain analysis, Poincare nonlinear analysis, cross-correlation analysis, and geometric measures, to extract features from waveform and clinical data. These features are then used for tasks such as patient phenotyping, disease subtyping, and dimensionality reduction using techniques like principal component analysis (PCA) and independent component analysis (ICA). The study highlights the challenge of interpretability in ML models, especially in clinical contexts, and emphasizes the importance of interdisciplinary collaborations between ML researchers and clinicians to improve model interpretability and clinical utility. The work [2] focuses on Android malware detection using machine learning algorithms, achieving a high precision rate of 98.98%. It presents a combination method that utilizes control flow graphs and Application Programming Interface (API) data sets to enhance malware detection models. The detection models are based on API calls, frequency, and sequence aspects, involving control flow graph construction, API information extraction, and creating boolean, frequency, and time-series data sets. The paper also discusses ensemble model development for Android malware detection, showcasing a comprehensive approach to improving the accuracy and effectiveness of malware detection in Android systems [3] focuses on wheat yield prediction using remote sensing and machine learning (ML) techniques, utilizing regression models such as Random Forest, XGBoost (XGB), and LASSO. Drone-based sensors are employed to collect multispectral data from wheat fields for accurate yield prediction. The study compares three regression techniques for wheat grain yield prediction, namely Random Forest, XGB, and LASSO, with a focus on data cleaning techniques to remove outliers and improve ML model performance. The LASSO regression model stands out with an R-squared (R2) value of 0.93 and Mean Absolute Error (MAE) of 21.72, demonstrating high accuracy in yield prediction. The use of drone-based multispectral sensors for data collection enhances the precision and reliability of wheat yield predictions in agricultural settings. The ML approaches for detecting wheel defects in railway systems using sensor data. These methods outperform classical defect detection techniques, particularly for flat spots, shelling, and non-roundness. The study utilizes sensor data to predict wheel defects during operation, leveraging novel features and ML models such as artificial neural networks (ANNs) trained on 2-D representations and support vector machines (SVMs) with custom features for time series data classification. Additionally, custom ANNs with convolutional layers and deep convolutional neural networks (CNNs) with wavelet features are employed for improved defect detection accuracy. These ML-based approaches offer enhanced performance in identifying wheel defects, showcasing the potential of ML in railway maintenance and safety [4]. The paper [5] focuses on utilizing ML techniques to optimize batch control systems for high-quality production processes in manufacturing. It introduces a two-stage approach that automates process control and accurately predicts sintering temperatures, aiming to enhance production quality. The ML models employed in this system extract interdependencies from data related to materials, processes, and quality, facilitating process optimization. The paper addresses shortcomings in manufacturing processes through ML techniques and introduces an original batch control process along with a two-stage model architecture for improved production outcomes [6] focuses on data-driven sensing, optimization, and control in process industries, discussing statistical and machine learning techniques for practical success. It emphasizes the importance of balancing deep learning approaches with domain knowledge to achieve effective results. The techniques mentioned include Principal Component Analysis (PCA), Multi-Layer Perceptron (MLP), Support Vector Regression (SVR), Gaussian Mixture Model (GMM), Bayesian Networks (BN), Relevance Vector Machine (RVM), Extreme Learning Machine (ELM), Partial Least Squares (PLS), and Least Absolute Shrinkage and Selection Operator (LASSO). The paper also mentions hybrid modeling, statistical learning, machine learning, deep learning, and reinforcement learning as essential approaches in the context of process industries. The paper explains MAC protocol recognition in communication networks, exploring methods to differentiate between various medium

© *JournalsPub 2024. All Rights Reserved*

access control protocols. It utilizes unsupervised clustering techniques to distinguish between reservation-based and random-access protocols, leveraging modular arithmetic for generating machine learning features from network traffic. Additionally, the study investigates MAC protocols designed for cognitive users and wireless sensor networks, while also examining machine learning and deep learning algorithms for MAC protocol recognition [7]. A predictive maintenance system for industrial machines using machine learning algorithms, achieving a high accuracy of 92% in classifying six types of machine stops. It utilizes data from IoT-enabled devices to prevent major failures and focuses on improving efficiency and reducing downtime in the textile industry. The system is based on AdaBoost for classifying machine stops, specifically in knitting machines, and involves training and optimizing the model using hyperparameter tuning and cross-validation techniques. Overall, the study highlights the effectiveness of machine learning-based predictive maintenance systems in enhancing industrial machine performance and reliability [8]. The paper [9] introduces a hybrid model-driven and data-driven control method for energy hubs (EHs), incorporating machine learning (ML) algorithms for optimization and control. It focuses on integrating AI technology to enhance energy management efficiency in EHs, addressing gaps in literature related to EH control with AI-based approaches. The hybrid method combines model-driven and data-driven control techniques with ML algorithms, including the use of least-squares algorithm for fitting data. The paper discusses EH control methods, energy savings, and the effects of applying these methods, highlighting varying energy-saving rates observed with different approaches in EH applications. The paper explores the application of data mining and machine learning techniques in global traffic management. It reviews 165 studies to categorize traffic management approaches utilizing technology, particularly focusing on real-time traffic information gathering, traffic density analysis, and the use of open-source tools. Additionally, the paper evaluates driver models, pedestrian interactions, pedestrian behavior factors, pedestrian-vehicle conflicts, and driving strategies to enhance traffic management strategies. It criticizes the lack of a standard approach in traffic management despite the numerous studies, categorizes existing approaches, and proposes new ideas to address this challenge [10].

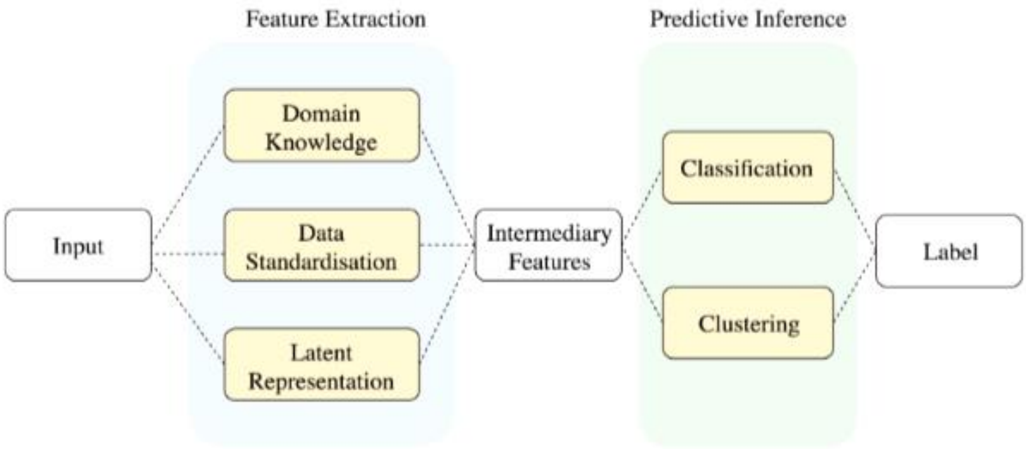

Figure 1. General ML pipeline.

Figure 1 shows the general ML pipeline that maps an input to a label. The two main steps of the pipeline are (1) extraction of an intermediary feature space and (2) label prediction using a classification or clustering algorith [1].

TECHNICAL ANALYSIS OF MACHINE LEARNING

Based on Some Applications on Various Industries

Healthcare

Before machine learning (ML), healthcare relied on traditional statistical analysis, expert systems, clinical decision support systems (CDSS), medical imaging tools, health information systems (HIS),

© JournalsPub 2024. All Rights Reserved

decision trees, rule-based algorithms, and data mining techniques. These methods, while valuable, were limited in handling complex data and providing personalized insights compared to ML. In healthcare, ML techniques are pivotal for developing outcome prediction models that analyze patient data to forecast various clinical outcomes. These models [1] undergoes a process starting with data pre-processing to clean, standardize, and prepare the data for analysis. Feature extraction techniques are then employed to identify relevant features, which may include statistical measures, time series analysis, and dimensionality reduction methods like Principal Component Analysis (PCA). ML models are trained using optimization algorithms such as gradient descent, and their performance is evaluated using metrics like accuracy and sensitivity. Despite their effectiveness, a notable challenge in ML models for healthcare lies in interpretability, prompting ongoing efforts to enhance model transparency and incorporate interpretability as a critical aspect of model assessment, ensuring trust and usability in clinical decision-making processes.

Cyber Security

The key aspects of cybersecurity include threat detection, risk management, incident response, encryption, access control, network security, application security, and user awareness training. The older, non-machine learning (ML) techniques used in Android malware detection had several limitations. Signature-based detection relied on known signatures, making it ineffective against new malware variants and zero-day attacks. Heuristic analysis and behavioral analysis often produced false positives or missed sophisticated malware. Static analysis and manual code review were resource-intensive and prone to oversight. Rule-based systems struggled with new threats that didn't fit predefined patterns. Blacklisting was reactive and couldn't handle new threats until identified and added to the blacklist. These limitations underscored the need for ML approaches, which can analyze data more comprehensively, detect patterns dynamically, and adapt to evolving threats without relying solely on predefined rules or signatures. From [2] Android malware detection using machine learning algorithms is a pivotal advancement in the realm of cybersecurity. For ensuring user safety, ML algorithms is constructed as a detection models based on control flow graphs and API information. The paper introduces a proactive approach to identify and mitigate Android malware threats. This methodology enables real-time monitoring, adaptability to evolving threats, and integration with existing cybersecurity frameworks, thus fortifying the overall security posture of mobile devices and systems. The Figure 2 shows the android malware detection architecture.

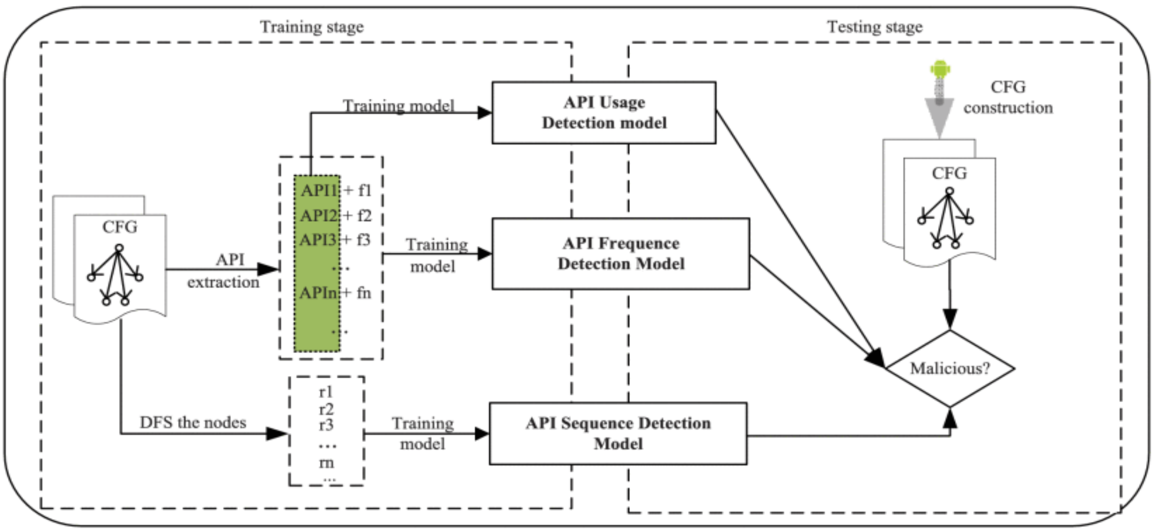

Figure 2. Detection architecture.

Agriculture

Machine learning (ML) is revolutionizing agriculture by offering advanced data-driven solutions across various aspects of farming and for wheat yield prediction. Compared to traditional methods like

© JournalsPub 2024. All Rights Reserved

field trials and statistical models, ML offers superior accuracy through algorithms like LASSO, which can capture non-linear relationships and handle diverse data sets from drone imagery to weather patterns. This shift exceeds limitations of past techniques, paving the way for highly precise and scalable yield predictions in modern agriculture. The paper [3] introduces a framework for predicting wheat grain yield that incorporates three regression techniques: Random Forest, Xtreme Gradient Boosting (XGB) regression, and Least Absolute Shrinkage & Selection Operator (LASSO) regression. LASSO regression stood out as the most effective technique, achieving an R-squared value of 0.93 and a mean absolute error (MAE) of 21.72, indicating superior predictive accuracy. This technique is good for handling high-dimensional data and mitigating overfitting issues, leading to improved performance and predictive power compared to Random Forest and XGB regression. The study's findings highlight LASSO regression's capability to manage multiple features efficiently, making it a favorable choice for wheat grain yield prediction tasks. The predicted grain yield for the various regression techniques versus actual yield is shown in Figure 3 [3].

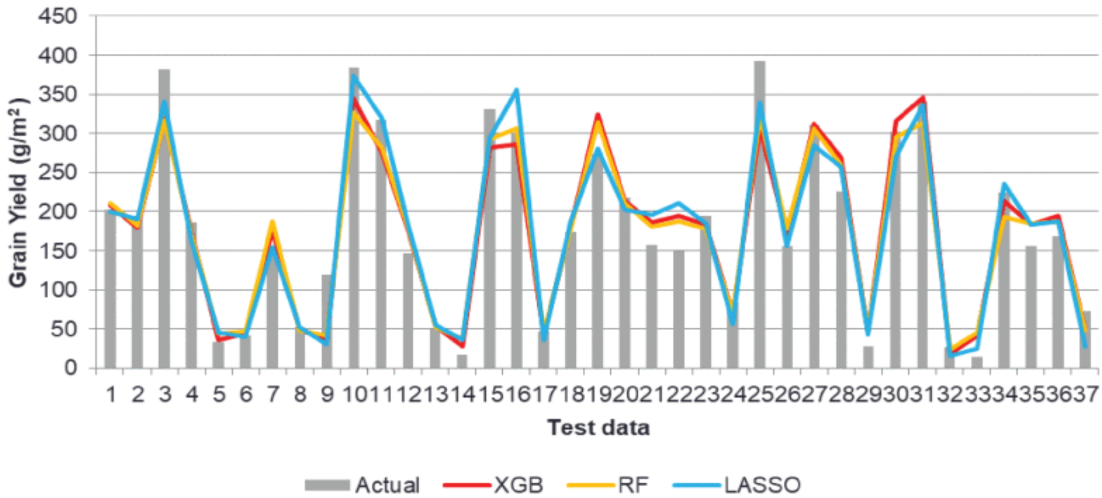

Figure 3. Deviation between the actual and predicted grain yield.

Railway Maintenance

While traditional methods like manual inspections played a role, they were labor-intensive, time-consuming, and prone to human error. Alternatively, rule-based systems using pre-set thresholds for defect detection offered some automation. However, these rules lacked flexibility and couldn't adapt to variations in defect types or severity. ML algorithms can automatically analyze vast amounts of sensor data, learning complex patterns to achieve superior accuracy in detecting a wider range of defects. In the area of Railway [4] Two machine learning methods were proposed for wheel defect detection in railway wagons based on the wheel vertical force measured by a sensor system on the railway network. The first method for classifying features as time series data and utilizes a support vector machine for classification. This method employs classical defect detection methods for flat spots and extends its predictive capabilities to other defect types. On the other hand, the second method employs custom artificial neural networks with convolutional layers on 2-D representations of the measurement time series. This approach enhances performance, particularly for wheels with flat spots and non-roundness. The evaluation of these methods includes metrics such as accuracy, precision, and recall, with both methods being trained automatically on measurements collected from defective and non-defective wheels. Notably, the second method, which utilizes deep convolutional neural networks, demonstrates superior performance in predicting flat spots, shelling, and non-roundness.

Communication Networks

Traditional methods for recognizing MAC protocols in communication networks had limitations. Rule-based systems, a common approach, struggled to adapt to new protocols as they required pre-

© JournalsPub 2024. All Rights Reserved

programmed rules for each type. This limited scalability, as manually defining rules for a vast number of protocols becomes impractical. Additionally, traditional techniques often relied on limited feature extraction, potentially missing subtle nuances in network traffic that differentiate protocols. Finally, their performance was static, requiring human intervention to update rules for new protocols or changing network conditions. Machine learning (ML) overcomes these limitations. Machine learning techniques are being used to recognize medium access control (MAC) protocols in communication networks [7]. Various supervised algorithms like support vector machines (SVM), k-nearest neighbors (k-NN), and Naive Bayes have been explored for building a protocol classifier. Additionally, a method using modular arithmetic combined with unsupervised k-means clustering helps differentiate between different protocols like time-division multiple access (TDMA) and carrier sense multiple access (CSMA). The accuracy levels achieved by these MAC recognition algorithms using classical machine learning techniques are on par with or better than similar works. Deep learning methods such as convolutional neural networks (CNNs) and long short-term memory (LSTM) models have also been applied for MAC protocol classification. The developed algorithm accurately identifies whether a network is using a single-channel CSMA or TDMA protocol or a hybrid protocol. Overall, the utilization of machine learning methods, including classical and deep learning techniques, enhances MAC protocol recognition in communication networks, with robust accuracy and applicability to diverse network conditions.

Energy Management

Optimizing energy hub control has traditionally been a challenge. Model-driven methods, relying on pre-programmed models, can be intricate and computationally expensive, especially for dynamic systems. On the other hand, data-driven methods, while simpler, require massive datasets and struggle with limited data or changing conditions. Machine learning (ML) offers a promising solution that bridges this gap. The hybrid model-driven and data-driven control method [9], which integrates machine learning algorithms, shows promise in energy hub applications. This approach combines the advantages of model-driven and data-driven methods to establish a relationship model between state variables, enabling accurate predictions with minimal data input. The machine learning algorithm utilized in this approach analyzes the impact of control variables on observed variables, extracts models, and optimizes data prediction by determining the optimal model dimensions and powers. It fits an analytical formula to the model based on available data. However, the effectiveness of technical analysis in machine learning and the choice of technique depends on factors such as the specific market analyzed, data availability and quality, and individual trading preferences and styles. Further research and evaluation are crucial to identify the most effective techniques and approaches for technical analysis in machine learning applications.

Traffic Management

Traditional traffic management often relied on manual data analysis and pre-set rules, which struggled with large datasets and offered limited adaptability to changing conditions. This resulted in inaccurate predictions and slow response times. Machine learning (ML) overcomes these limitations by automatically processing vast amounts of data, uncovering hidden patterns, and continuously adapting to evolving traffic dynamics. The integration of data mining and machine learning technologies in traffic management to detect and predict traffic patterns effectively are proposed in [10]. Data mining is described as the process of analyzing, predicting, and uncovering knowledge from vast datasets, while machine learning methods are utilized for processing and analyzing traffic data to enhance decision-making capabilities. The study critically reviews approximately 165 studies and categorizes them based on their strategies in traffic management using data mining and machine learning techniques. Notably, the paper underscores the absence of a standardized approach to traffic management acknowledged by the traffic management community, highlighting the need for innovative solutions. The Figure 4 given below shows the proposed traffic management conceptual model [10].

© *JournalsPub 2024. All Rights Reserved*

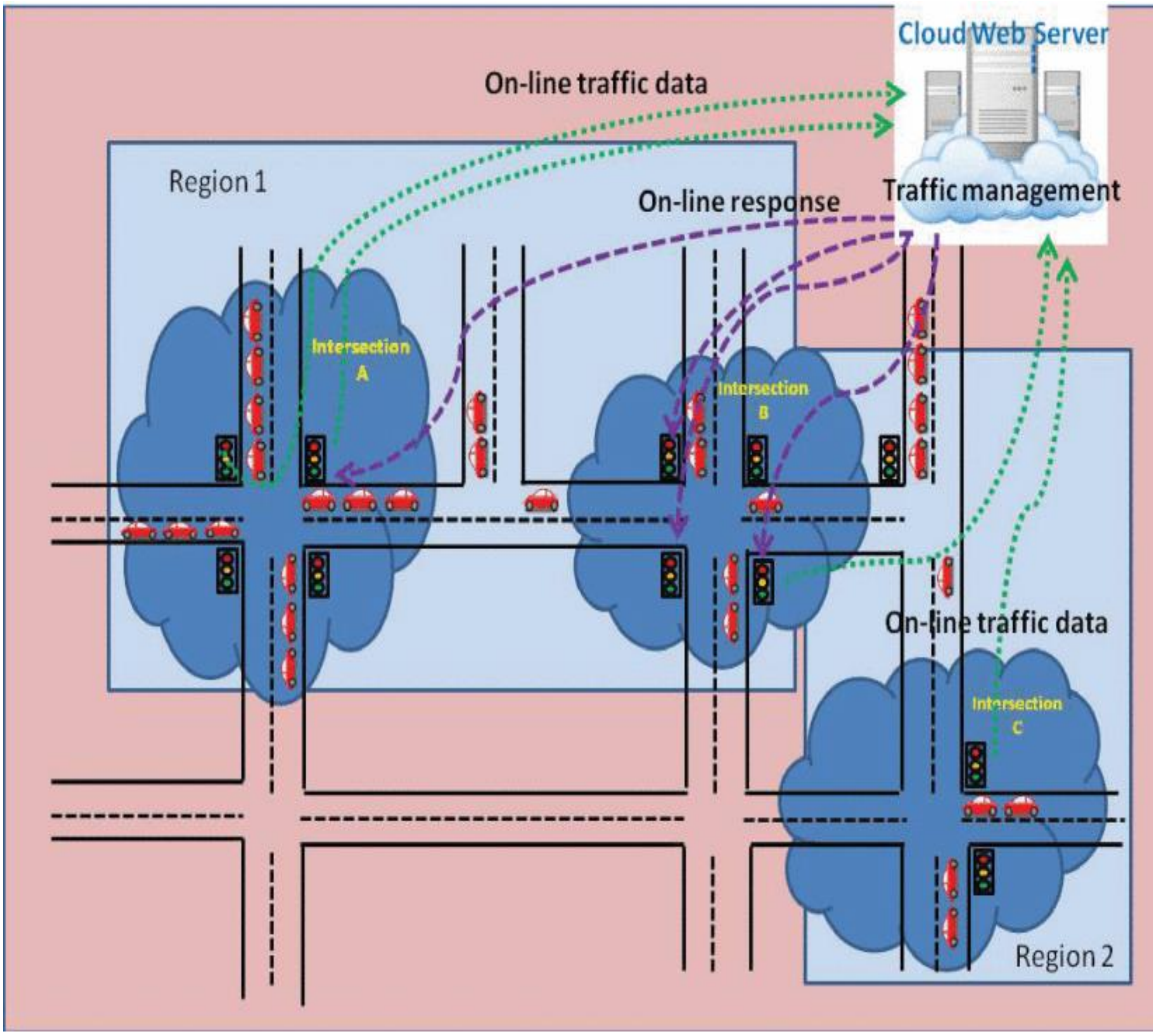

Figure 4. The proposed traffic management conceptual model.

Process Industries

ML has become the go-to approach for soft sensing in process industries due to its distinct advantages over traditional methods. Unlike traditional techniques that rely on pre-defined models, ML algorithms can learn complex relationships from data, making them highly adaptable to dynamic processes This flexibility surpasses the limitations of statistical methods, which often struggle with intricate non-linear relationships between variables. Additionally, ML excels at handling high-dimensional data**,** a common characteristic of process monitoring. ML techniques play a crucial role in soft sensing applications within the process industries [6], representing one of the most widespread industrial applications of ML. Various statistical and machine learning methods like principal component analysis (PCA), slow feature analysis, independent component analysis, and factorial analysis have proven successful in soft sensing tasks. Hybrid modeling approaches, which integrate statistical and ML techniques with mathematical programming or reinforcement learning, are commonly employed for data-driven optimization and control in these industries. Notably, fast ML algorithms like Extreme Learning Machine (ELM) and Generalized Regression Neural Network (GRNN) are favored for their efficiency, with ELM particularly noted for its speed due to its lack of learnable parameters. Nevertheless, the accuracy of ML methods can vary based on several factors including the volume of training data, number of features, training algorithm used, and the architecture of the network.

COMPARATIVE STUDY

Comparative study involves use of various techniques in different fields is shown in Table 1.

© JournalsPub 2024. All Rights Reserved

Table 1. Comparative study involves use of various techniques in different fields.

Study	Field	Techniques	Benefits	Challenges	Key Findings
[1]	Healthcare	Fourier transforms, wavelet transforms, time domain analysis, cross-correlation analysis, geometric measures, PCA, ICA	Improved diagnosis and treatment planning	Interpretability of models for clinical decision-making	Interpretability challenge in clinical contexts; Importance of collaboration between ML researchers and clinicians
[2]	Cyber-Security	Control flow graphs, API data sets	Enhanced Malware detection and threat prevention	Data security and Privacy Concerns	98.98% precision rate for malware detection using combination of control flow graphs and API data
[3]	Agriculture	Random Forest, XG Boost (XGB), LASSO	Increased crop yield and prediction accuracy	Availability and quality of agricultural data	LASSO regression model achieves high accuracy (R^2=0.93, MAE=21.72)
[4]	Railway maintenance	Artificial neural networks (ANNs), support vector machines (SVMs), convolutional neural networks (CNNs)	Improved wheel defect detection and prevention	Real-time implementation and integration with existing systems	ML models outperform classical techniques for wheel defect detection
[5]	Manufacturing	Two stage ML process	Optimized production processes and reduced waste	Explainability of model decisions for process control	Automates process control, predicts sintering temperatures
[6]	Process Industry	PCA, MLP, SVR, GMM, BN, RVM, ELM, PLS, LASSO	Enhanced process efficiency and control	Integration of domain knowledge with complex ML models	Statistical and machine learning techniques for practical success
[7]	Communication Networks	Unsupervised clustering techniques	Efficient network management and protocol identification	Scalability and adaptability to evolving network traffic patterns	Differentiates between reservation-based and random-access protocols
[8]	Predictive maintenance	AdaBoost	Reduced downtime and improved machine reliability	Sensor data quality and potential for false positives	92% accuracy in classifying six machine stop types
[9]	Energy management	Hybrid model-driven and data-driven control with machine learning	Optimized energy consumption and reduced cost	Integration of ML models with existing energy infrastructure	Integrates AI for energy efficiency in energy hubs
[10]	Traffic Management	Data mining and machine learning techniques	Reduced traffic	Ethical considerations of data collection and privacy	Review existing models & proposes new ideas for traffic management

CONCLUSIONS

As the field of ML continues to evolve, ongoing research and development are crucial to ensure responsible implementation and maximize its positive impact on society. In healthcare, ML is harnessed for outcome prediction models using electronic health records and various techniques for feature extraction, emphasizing the need for interpretable models in clinical settings. Another study focuses on Android malware detection, achieving high precision through a combination of control flow graphs and API data sets. Agriculture benefits from ML in wheat yield prediction using remote sensing data, while railway systems employ ML for defect detection, enhancing safety. ML's role extends to optimizing manufacturing processes, with a two-stage approach for batch control and sintering temperature prediction. In process industries, ML aids in data-driven sensing, optimization, and control, highlighting the importance of combining deep learning with domain knowledge. Furthermore, ML contributes to

© *JournalsPub 2024. All Rights Reserved*

MAC protocol recognition in communication networks, predictive maintenance systems in industrial settings, and energy hub control methods. Finally, ML techniques are explored in global traffic management, emphasizing the ongoing need for standardized approaches in this field. Overall, these studies underscore ML's versatility and effectiveness in solving complex problems across industries.

Acknowledgement

We would like to express my sincere gratitude to all those who contributed to the completion of this review paper. Firstly, we extend our heartfelt appreciation to the authors of the primary studies we analyzed, whose research laid the foundation for our work. we are also grateful to the faculties whose insightful comments and suggestions significantly improved the quality and clarity of this manuscript. Additionally, we acknowledge the support and guidance provided by our friends and mentors throughout the writing process. Lastly, we would like to thank our families for their unwavering encouragement and understanding during this endeavor.

REFERENCES

1. F. Shamout, T. Zhu and D. A. Clifton. Machine Learning for Clinical Outcome Prediction. IEEE Reviews in Biomedical Engineering. 2021; vol. 14, pp. 116–126.
2. Z. Ma, H. Ge, Y. Liu, et al. A Combination Method for Android Malware Detection Based on Control Flow Graphs and Machine Learning Algorithms. IEEE Access, 2019; vol. 7, pp. 21235–21245.
3. U. Shafi *et al*. Tackling Food Insecurity Using Remote Sensing and Machine Learning-Based Crop Yield Prediction. IEEE Access. 2023; vol. 11, pp. 108640–108657.
4. G. Krummenacher, C. S. Ong, S. Koller, et al. Wheel Defect Detection with Machine Learning. IEEE Transactions on Intelligent Transportation Systems. 2018; vol. 19, no. 4, pp. 1176–1187.
5. Meiners, M., Mayr, A., Thomsen, M, et al. Application of machine learning for product batch oriented control of production processes. Procedia CIRP. 2020; vol. 93, pp. 431–436.
6. Lawrence, N. P., Damarla, S. K., Kim, J. W, et al. Machine learning for industrial sensing and control: A survey and practical perspective. Control Engineering Practice. 2024; vol. 145, pp. 105841.
7. M. M. Rooney and M. K. Hinders. Machine Learning for Medium Access Control Protocol Recognition in Communications Networks. IEEE Access.2021; vol. 9, pp. 110762–110771.
8. Elkateb, S., Métwalli, A., Shendy, A., et al. Machine learning and IoT–Based predictive maintenance approach for industrial applications. Alexandria Engineering Journal, 2024; vol. 88, pp. 298-309.
9. G. Cerar, H. Yetgin, C. Fortuna, et al. Machine Learning for Wireless Link Quality Estimation: A Survey. IEEE Communications Surveys & Tutorials. 2021; vol. 23, no. 2, pp. 696–728.
10. N. O. Alsrehin, A. F. Klaib and A. Magableh. Intelligent Transportation and Control Systems Using Data Mining and Machine Learning Techniques: A Comprehensive Study. IEEE Access.2019; vol. 7, pp. 49830–49857.

© *JournalsPub 2024. All Rights Reserved*