STM JOURNALS

Recent Trends in
Fluid Mechanics

ISSN: 2455-1961
Volume 12, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RTFM

https://journals.stmjournals.com/rtfm

Review RTFM

IoT Sensors to Monitor Pipeline Pressure and Flow Rate Combined with ML-Algorithms to Detect Leakages

Nikat Rajak Mulla[1,*], Kazi Kutubuddin Sayyad Liyakat[2]

Abstract

In the field of fluid mechanics, pipelines are the lifeblood of industries, transporting everything from natural gas and oil to water and chemicals. Maintaining their integrity is paramount for safety, economic efficiency, and environmental protection. Traditional leak detection methods explained in fluid mechanics can be slow, expensive, and sometimes fail to identify small leaks early enough to prevent significant damage. However, the convergence of Internet of Things (IoT) and Machine Learning (ML) is ushering in a new era of proactive and intelligent pipeline management. The core of this revolution lies in the deployment of IoT sensors along the pipeline's length. These sensors provide a constant stream of real-time data on critical parameters. As sensor technology and data analysis methods continue to improve, their applications in pipeline systems are expected to grow even further. These advancements support not only more secure and efficient pipeline operations but also contribute to long-term sustainability goals. The adoption of these technologies marks a shift toward smarter infrastructure and more reliable resource management for the future. The raw data from IoT sensors is not immediately actionable. It needs to be processed, analyzed, and compared against historical trends and operational parameters. The integration of Machine Learning (ML) with Internet of Things (IoT) technology is bringing significant improvements to the way pipelines are monitored and maintained. By utilizing smart sensors along pipelines, it becomes possible to gather real-time data on essential parameters such as pressure, flow rate, and temperature. ML algorithms process this data to detect unusual patterns or changes that could indicate issues like leaks or structural weaknesses. This approach provides a more efficient and intelligent way to manage fluid transport systems and is becoming increasingly relevant in the field of fluid mechanics. Traditional pipeline monitoring methods are often reactive, addressing problems only after they occur. In contrast, the combination of IoT and ML enables predictive maintenance by identifying problems early, allowing operators to take action before serious damage happens. This leads to improved safety, reduced repair costs, and minimized environmental harm. ML algorithms excel at this task. The combination of IoT sensors and machine learning algorithms is revolutionizing pipeline monitoring like flow rate, pressure, and offering a powerful and proactive approach to leak detection and prevention. This is employing in the study of fluid mechanics. By embracing these technologies, pipeline operators can significantly improve safety, reduce costs, and minimize their environmental impact, paving the way for a more sustainable and secure future. As the technology continues to evolve, we can expect even greater advancements in pipeline management, ensuring the safe and efficient transportation of vital resources for generations to come.

Keywords: Fluid mechanics, flow rate, pipe leakage, pipeline, pressure, IoT, machine learning

***Author for Correspondence**
Nikat Rajak Mulla
E-mail: nikatmulla786@gmail.com

[1]Student, Department of Electronics and Telecommunication Engineering, Brahmdevdada Mane Institute of Technology, Solapur, Maharashtra, India
[2]Professor and Head, Department of Electronics and Telecommunication Engineering, Brahmdevdada Mane Institute of Technology, Solapur, Maharashtra, India

Received Date: May 31, 2025
Accepted Date: June 02, 2025
Published Date: July 10, 2025

Citation: Nikat Rajak Mulla, Kazi Kutubuddin Sayyad Liyakat. IoT Sensors to Monitor Pipeline Pressure and Flow Rate Combined with ML-Algorithms to Detect Leakages. Recent Trends in Fluid Mechanics. 2025; 12(2): 40–48p.

INTRODUCTION

In the field of fluid mechanics, pipelines are the essence of activities like transporting crucial resources like oil, gas, and water across vast distances. However, they are also susceptible to leaks, which can lead to significant financial losses, environmental damage, and even safety hazards. Traditional leak detection methods are often reactive, relying on manual inspections or large-scale flow discrepancies, leading to delayed responses and amplified consequences [1–4].

Fortunately, a new approach leveraging the power of Internet of Things (IoT) and Machine Learning (ML) is revolutionizing pipeline monitoring and leak detection. This innovative combination provides real-time insights, enabling proactive intervention and minimizing potential damages.

The integrity of pipelines is paramount, especially given the potential environmental damage, economic losses, and safety hazards associated with leaks. Traditional inspection methods are often costly, time-consuming, and incapable of providing real-time insights into pipeline health. This has led to a surge in research and implementation of innovative solutions leveraging the power of IoT and ML. This article emphasizes on the efficacy of using IoT sensors to monitor pipeline pressure and flow rate, coupled with ML algorithms for early leak detection [5–15].

The incorporation of IoT sensors for continuous pressure and flow rate monitoring offers a significant leap forward in pipeline management. These sensors, strategically deployed along the pipeline, provide a constant stream of data that paints a comprehensive picture of operational conditions. This real-time data allows for immediate identification of anomalies that might indicate a developing leak, a vast improvement over periodic manual inspection [16–25].

The foundation of this smart pipeline system lies in the strategic deployment of IoT sensors along the pipeline's length. These sensors are specifically designed to measure critical parameters with high precision and frequency. Key parameters (Figure 1) monitored include:

- *Pressure*: Continuous monitoring of pressure allows for the identification of sudden drops, which can be a clear indicator of a leak.
- *Flow rate*: Monitoring the rate at which fluid flows through the pipeline, both at the entry and exit points, can reveal inconsistencies indicative of losses.
- *Temperature*: While not directly indicative of leaks, temperature fluctuations can influence pressure and flow, providing valuable context for analysis.
- *Vibration (optional):* In certain scenarios, vibration sensors can detect anomalies caused by leaks, particularly in areas prone to corrosion or damage.

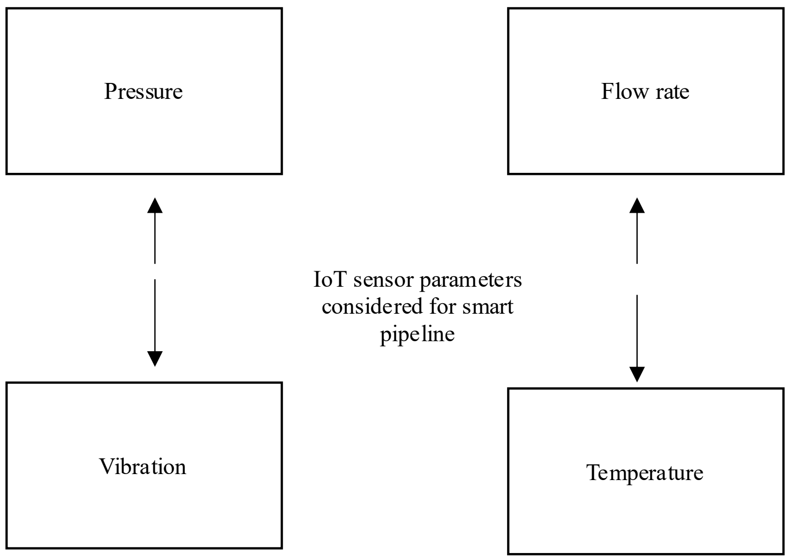

Figure 1. Key parameters considered for smart pipeline.

These sensors transmit data wirelessly to a central processing unit, creating a constant stream of information about the pipeline's operational status. This real-time data stream is the fuel that powers the next crucial component: ML algorithms [26–30].

The raw data from the IoT sensors is valuable, but its true potential is unlocked through the application of machine learning. Sophisticated ML algorithms are trained on historical data, including both normal operational parameters and instances of past leaks. This training allows the algorithms to:

- *Identify anomalies*: By learning the expected behavior of the pipeline under various conditions, the ML model can identify deviations from the norm, flagging potential leaks even before they become significant.
- *Predict future events*: Based on historical trends and current conditions, the ML algorithm can predict the likelihood of future leaks, allowing for proactive maintenance and preventative measures.
- *Reduce false alarms*: By considering multiple parameters simultaneously and learning complex patterns, the ML model can significantly reduce the number of false alarms, saving valuable time and resources.
- *Improve efficiency*: Data analysis can optimize pipeline operations by identifying areas of inefficiency and suggesting adjustments to improve flow and reduce energy consumption.

The value of this data is further amplified when paired with sophisticated ML algorithms. These algorithms, trained on historical operational data and leak simulations, can identify subtle deviations from normal patterns that would be imperceptible to human operators. By analyzing the interplay between pressure and flow rate variations over time, ML models can distinguish between routine fluctuations caused by operational changes and anomalies indicative of a potential leak. This predictive capability enables proactive intervention, reducing potential damage and downtime.

The integration of IoT and ML in pipeline monitoring offers a multitude of benefits:

- *Faster leak detection*: Real-time monitoring and anomaly detection allows for rapid identification of leaks, minimizing the amount of fluid lost and the extent of environmental damage.
- *Reduced costs:* By preventing leaks and optimizing operations, the system can significantly reduce operational costs associated with lost product, remediation, and maintenance.
- *Improved safety*: Early leak detection and preventative maintenance enhance overall safety by reducing the risk of catastrophic failures and related hazards.
- *Enhanced environmental protection*: Minimizing leaks and spills protects the environment and reduces the potential for long-term contamination and ecological damage.
- *Data-driven decision making*: The system provides valuable insights into pipeline performance, enabling informed decisions regarding maintenance, upgrades, and operational strategies.

While the potential benefits are significant, implementing a smart pipeline system requires careful planning and consideration:

- *Sensor placement and accuracy*: Strategic sensor placement is crucial for capturing representative data. Sensor accuracy and calibration are essential for reliable monitoring.
- *Data security*: Protecting the sensitive data collected by the sensors is paramount. Robust security measures are necessary to prevent unauthorized access and manipulation.
- *Connectivity:* Reliable wireless connectivity is essential for transmitting data from the sensors to the central processing unit, especially in remote areas.
- *Algorithm training and maintenance*: The ML algorithms require continuous training and refinement to maintain accuracy and adapt to changing conditions.
- *Cost of implementation*: The upfront investment in sensors, infrastructure, and software can be substantial. However, the long-term benefits often outweigh the initial costs.

Smart pipelines powered by IoT sensors and machine learning represent a significant advancement in pipeline monitoring and leak detection. By providing real-time insights, enabling predictive analysis, and reducing response times, these systems offer a more efficient, safer, and environmentally responsible approach to managing critical infrastructure. As technology continues to evolve and the cost of sensors decreases, the adoption of smart pipeline solutions is poised to accelerate, leading to a more sustainable and reliable future for the industries that depend on them.

SMART PIPES: LEVERAGING IoT AND MACHINE LEARNING TO DETECT PIPELINE LEAKS

Maintaining pipelines integrity is paramount, as leaks can lead to significant environmental damage, economic losses, and potential safety hazards. Traditional leak detection methods are often reactive, relying on manual inspections or waiting for noticeable pressure drops. However, advancements in IoT and ML are paving the way for proactive and intelligent pipeline monitoring systems. This article explores the design and implementation of such a system, focusing on the synergy of IoT sensors and ML algorithms to detect pipeline leaks early and efficiently as shown in Figure 2.

Step 1: Sensor Selection and Placement for Comprehensive Monitoring

The foundation of a successful leak detection system lies in accurate and real-time data acquisition. This requires strategic deployment of IoT sensors:

- *Pressure sensors:* These are crucial for detecting pressure drops, a key indicator of leaks. High-precision pressure sensors should be strategically placed along the pipeline, particularly at intervals dictated by the pipeline's length, material, and operating pressure. Consider placing sensors at vulnerable points such as joints, welds, and areas prone to corrosion.
- *Flow rate sensors*: Monitoring the volume of liquid or gas flowing through the pipeline is equally important. Discrepancies between inflow and outflow rates can signify a leak. Ultrasonic flow meters are a popular choice due to their non-intrusive nature and accuracy. They can be placed along the pipeline to measure flow rates at different points.
- *Acoustic sensors*: Specialized acoustic sensors can detect the subtle sounds emitted by leaks, even before significant pressure drops occur. These sensors are typically highly sensitive and require careful calibration to filter out ambient noise. They can be deployed externally on the pipeline or internally using "smart pigs" that travel through the pipeline.
- *Temperature sensors*: Changes in temperature, particularly localized drops, can also indicate leaks due to the expansion and contraction of the conveyed substance as it escapes. Placing temperature sensors alongside pressure and flow sensors provides valuable supplementary data.

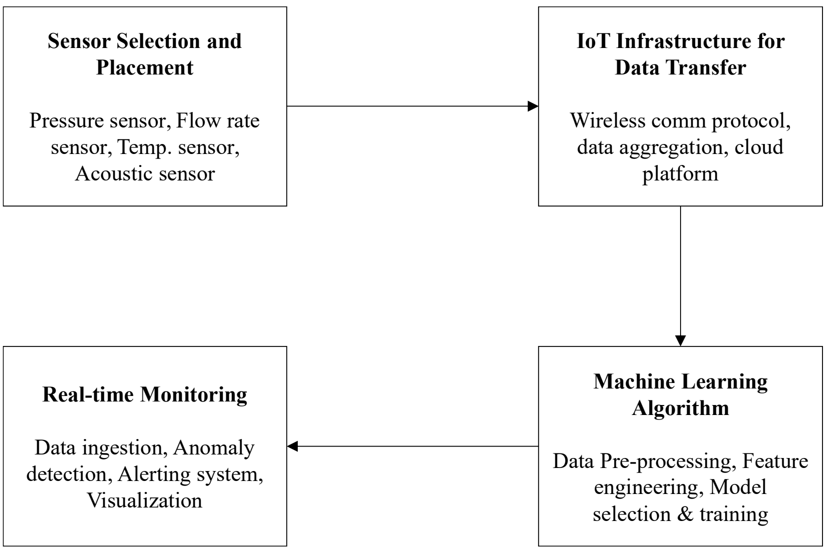

Figure 2. Design steps in smart pipeline.

Step 2: Building the IoT Infrastructure for Seamless Data Transmission

Once the sensors are chosen, a robust IoT infrastructure is needed to collect, transmit, and store the data:

- *Wireless communication protocols:* Choose a suitable wireless communication protocol based on the range, bandwidth, and power consumption requirements. Options include:
  - *Cellular (4G/5G):* Ideal for long-distance communication with wide coverage.
  - *LoRaWAN:* For long-range, low-power applications.
  - *NB-IoT*: Designed for connecting a large number of devices with low bandwidth requirements.
  - *Zigbee or Bluetooth*: For shorter-range communication, often used within sensor clusters or near a gateway.
- *Data aggregation and gateways*: Sensor data needs to be aggregated and transmitted to a central processing unit. Gateways act as intermediaries, collecting data from sensors and forwarding it to a cloud platform or on-premise server. These gateways often perform edge computing tasks like data pre-processing and filtering.
- *Cloud platform for data storage and processing*: A cloud platform provides scalable storage and powerful computing resources for data analysis and ML model training. Popular platforms include AWS IoT, Azure IoT Hub, and Google Cloud IoT Platform.

Step 3: Developing Machine Learning Algorithms for Anomaly Detection

The core of intelligent leak detection lies in the application of ML algorithms to analyze the sensor data and identify anomalies that indicate leaks.

- *Data pre-processing*: The raw sensor data must be cleaned, transformed, and normalized before being fed into the ML models. This includes handling missing values, removing noise, and standardizing data formats.
- *Feature engineering*: Selecting relevant features from the data is crucial for model performance. Examples include:
  - Pressure gradients between adjacent sensors
  - Flow rate differences at different points
  - Rolling averages of pressure and flow over time
  - Statistical features like standard deviation and variance
- *Model selection and training*: Several ML algorithms can be used for leak detection, each with its strengths and weaknesses:
  - *Supervised learning*: Train a model on labeled data (with and without leaks) to predict future leak events. Algorithms like Support Vector Machines (SVM), Random Forests, and Neural Networks can be effective.
  - *Unsupervised learning*: Identify anomalies in the data without requiring labeled data. Algorithms like One-Class SVM, Isolation Forest, and Autoencoders can detect deviations from normal operating conditions.
  - *Time series analysis*: Use algorithms like ARIMA or LSTM (Long Short-Term Memory) to model the temporal dependencies in the sensor data and predict future values. Significant deviations from the predicted values can indicate a leak.
- *Model evaluation and tuning*: Evaluate the performance of the trained models using metrics like precision, recall, F1-score, and AUC. Tune the model parameters to optimize its performance on unseen data.

Step 4: Real-Time Monitoring and Alerting

The final step involves deploying the trained ML model in a real-time monitoring system:

- *Real-time data ingestion*: Continuously ingest sensor data from the IoT infrastructure into the ML model.
- *Anomaly detection in real-time*: The ML model analyzes the incoming data and identifies anomalies.

- *Alerting system*: If the model detects a significant anomaly, it triggers an alert to notify operators. Alerts can be delivered via email, SMS, or through a dedicated monitoring dashboard.
- *Visualization and reporting*: A user-friendly dashboard provides a visual representation of the pipeline's status, sensor data, and alert history.

Benefits of IoT-Based Pipeline Leak Detection:
- *Early leak detection*: Proactive detection of leaks before they escalate into major incidents.
- *Reduced environmental impact*: Minimizing the release of hazardous substances into the environment.
- *Improved safety*: Protecting human life and infrastructure.
- *Cost savings*: Reducing product loss, repair costs, and regulatory penalties.
- *Enhanced operational efficiency*: Optimizing pipeline operations and maintenance.

By combining the power of IoT sensors and ML algorithms, it's possible to create intelligent pipeline monitoring systems that can significantly improve leak detection accuracy, response time, and overall pipeline safety. While the initial investment in sensor deployment and infrastructure setup might be substantial, the long-term benefits in terms of reduced risks, cost savings, and environmental protection make it a worthwhile endeavor. As technology continues to evolve, these systems will become even more sophisticated and reliable, playing a crucial role in ensuring the safe and efficient transportation of vital resources.

DISCUSSION

Ensuring pipelines integrity is paramount, not only for economic reasons but also for environmental protection and public safety. Traditional inspection methods can be costly, time-consuming, and often reactive, only identifying leaks after they have already occurred. However, a powerful new approach is emerging, leveraging the power of IoT sensors and machine learning (ML) algorithms to detect leaks proactively and minimize their impact.

This approach hinges on the synergistic relationship between real-time data acquisition and intelligent analysis. By strategically deploying IoT sensors along pipelines, we can continuously monitor critical parameters like pressure and flow rate. These sensors, often wireless and battery-powered, transmit data to a central system for analysis.

These sensors act as our eyes and ears on the pipeline, providing a granular view of its operational condition. Here's how they contribute:
- *Pressure sensors*: Monitoring pressure drops is a key indicator of potential leaks. Sudden or gradual pressure declines, particularly in areas where no consumption is expected, can signal a breach in the pipeline's integrity.
- *Flow rate sensors*: Similarly, unusual changes in flow rate can indicate leaks or blockages. By comparing flow rates at different points along the pipeline, we can pinpoint the approximate location of anomalies.
- *Beyond pressure and flow*: Depending on the application and environment, other sensors can also be incorporated. These might include temperature sensors to detect thermal anomalies, acoustic sensors to listen for the sound of escaping fluids, and even strain sensors to monitor structural integrity.

While sensor data provides a wealth of information, it's the application of machine learning that truly unlocks its potential. ML algorithms can be trained on historical data to:
- *Establish baseline behavior*: By learning the normal operating parameters of the pipeline under varying conditions (e.g., temperature, weather, flow demands), the ML model creates a baseline.
- *Detect anomalies*: The model then continuously compares real-time sensor data to this baseline, identifying deviations that could indicate a leak.

- *Predict future issues*: In some cases, ML can even predict potential leaks before they occur by recognizing subtle patterns in the data that precede failures.
- *Reduce false positives*: By incorporating various factors and understanding the nuances of the pipeline's operation, ML algorithms can significantly reduce the number of false alarms, preventing unnecessary investigations.

The combination of IoT sensors and ML algorithms offers a multitude of advantages compared to traditional leak detection methods:

- *Early leak detection*: Proactive identification allows for faster response times, minimizing the impact of leaks on the environment and infrastructure.
- *Reduced operational costs*: Automated monitoring reduces the need for manual inspections, saving time and resources.
- *Improved safety*: By quickly identifying and mitigating potential hazards, this approach contributes to a safer operating environment for workers and the public.
- *Increased efficiency*: Optimized pipeline maintenance and reduced downtime contribute to overall efficiency and profitability.
- *Data-driven decision making*: Provides valuable insights into pipeline performance, enabling informed decisions about maintenance and optimization.

The future of pipeline leak detection lies in the continued development and refinement of IoT sensor technology and machine learning algorithms. As sensor technology becomes more affordable and reliable, and as ML algorithms become more sophisticated, we can expect to see even more widespread adoption of this proactive approach.

Ultimately, the combination of smart sensors and AI provides a powerful tool for protecting our valuable pipeline infrastructure, ensuring safer operations, and minimizing the environmental impact of potential leaks. By embracing this technology, industries can move towards a more sustainable and responsible future.

CONCLUSION

In fluid mechanics, the pipeline study is important. The integrity of pipelines is paramount, especially given the potential environmental damage, economic losses, and safety hazards associated with leaks. The pipelines are having flow and pressure of liquid. In the field of fluid mechanics, the study of pipelines is critical due to their role in transporting liquids under varying pressure and flow conditions. Ensuring the structural integrity of these pipelines is essential, considering the severe environmental, economic, and safety risks associated with potential leaks or failures. Traditional inspection methods, though foundational in fluid mechanics, are often expensive, time-intensive, and lack the capability for real-time monitoring. These limitations have catalyzed a growing interest in the adoption of advanced technologies, particularly those involving the Internet of Things (IoT) and Machine Learning (ML). Traditional inspection methods suggested in fluid mechanics for pipeline inspection are often costly, time-consuming, and incapable of providing real-time insights into pipeline health. This has led to a surge in research and implementation of innovative solutions leveraging the power of IoT and ML. The combination of IoT sensors for real-time pressure and flow rate monitoring with ML algorithms for leak detection represents a powerful solution for safeguarding pipelines. This technology offers significant advantages in terms of early leak detection, reduced operational costs, improved safety, and enhanced asset management. The integration of IoT sensors enables continuous monitoring of flow rate and pressure across the pipeline network, while ML algorithms process this data to identify irregularities and predict potential failures. This approach significantly improves early leak detection, lowers maintenance and operational costs, enhances safety, and supports better asset management. However, for successful deployment, several critical factors must be addressed, including sensor selection and strategic placement, data quality and cybersecurity, algorithm training and accuracy, system integration, and adherence to regulatory standards. While careful planning and execution are essential for successful implementation, the potential benefits of this approach far outweigh the challenges. As sensor technology continues to evolve and ML algorithms become more sophisticated, this integrated approach will undoubtedly play an increasingly important role in ensuring the long-term integrity and safety of pipeline infrastructure worldwide. However, the successful implementation of this technology requires careful consideration of several factors like Sensor Selection and Placement, Data Quality and Security, Algorithm Selection and Training, Infrastructure and Integration and Regulatory Compliance. As sensor capabilities and machine learning models continue to evolve, the synergy between these technologies is poised to revolutionize pipeline monitoring systems globally. Further research is needed to explore scalable deployment strategies, cross-domain applications in different fluid systems, and the development of standardized protocols for real-time diagnostics and decision-making.

REFERENCES

1. Mishra SB, Liyakat KK. AI-Driven-IoT (AIIoT) Based Decision-Making in Molten Metal Processing. J Ind Mech. 2024 Nov 21;9(2):45–56.
2. Liyakat KK, Halli UM. Nanotechnology in IoT security. Journal of Nanoscience, Nanoengineering & Applications (JONSNEA). 2022;12(3):11–6.
3. Devanand WA, Raghunath RD, Baliram AS, Kazi K. Smart agriculture system using IoT. Int J Innov Res Technol. 2019 Mar;5(10).
4. Liyakat KK. Detection of Malicious Nodes in IoT Networks based on packet loss using ML. J Mobile Comput Commun Mobile Netw. 2022;9:9–17.
5. Liyakat KK. Model for Agricultural Information system to improve crop yield using IoT. Journal of Open Source Development (JoOSD). 2022;9(2):16–24.
6. Aavula R, Deshmukh A, Mane VA, Chavhan GH, Liyakat KK. Design and Implementation of sensor and IoT based Remembrance system for closed one. Telematique. 2022;21(1):2769–78.
7. Kazi Kutubuddin SL. A novel design of IoT based 'love representation and remembrance' system to loved one's. Gradiva Rev J. 2022;8(12):377–83.
8. Kazi KS. IoT based healthcare system for home quarantine people. J Instrum Innov Sci. 2023;8(1):1–8.
9. Liyakat KK. IoT-Based Weather Information Prototype Using WeMos. Journal of Control and Instrumentation Engineering (JoCI). 2023;9(1):10–22.
10. Ravi A. Pattern Recognition-An Approach towards Machine Learning, Lambert Publications, 2022.
11. Khatun MA, Chowdhury N, Uddin MN. Malicious nodes detection based on artificial neural network in iot environments. In2019 22nd International Conference on Computer and Information Technology (ICCIT) 2019 Dec 18. pp. 1–6.
12. Kazi KS. IoT-based healthcare monitoring for COVID-19 home quarantined patients. Recent Trends in Sensor Research & Technology (RTSRT). 2022;9(3):26–32.
13. Kutubuddin K. Blockchain-enabled IoT environment to embedded system a self-secure firmware model. Journal of Telecommunication Study (JTS). 2023;8(1).
14. Kutubuddin K. A Study HR Analytics Big Data in Talent Management. Research and Review: Human Resource and Labour Management (RRHRLM). 2023;4(1):16–28.
15. Chinthamu N, Prasad M, Chinchawade AJ, Liyakat KK, Deepti K, Karukuri M, Kumar CM. Self-Secure firmware model for Blockchain-Enabled IOT environment to Embedded system. Eur Chem Bull. 2023;12:S3.
16. Nerkar PM, Shinde SS, Liyakat KK, Desai S, Kazi SS. Monitoring fresh fruit and food using IoT and machine learning to improve food safety and quality. Tuijin Jishu/J Propuls Technol. 2023;44(3):2927–31.
17. Liyakat KS, Liyakat KK. ML in the electronics manufacturing industry. Journal of Switching Hub (JoSH). 2023;8(3):9–13.
18. Liyakat KK. Brand Protection Using Machine Learning: A New Era. E-Commerce for Future & Trends (ECFT). 2025;12(1):33–44p.
19. Suryagan AA, Nemte AL, Thorat KD, Khadake SB. IoT Based Flood Monitoring System by using Thing Speak Cloud. International Journal of Advanced Research in Science, Communication and Technology (IJARSCT). 2025;5(4):666–687.

20. Liyakat KS. e-Skin Applications in Healthcare and Robotics: A Study. Journal of Advancements in Robotics (JoARB). 2025;12(1):13–-21.
21. Chavare SM, Nanaware PP, Wagh SS, Jadhav AT, Yogesh Y, Khadake SB. Smart Plant Monitoring and Automated Irrigation System Using IOT. International Journal of Advanced Research in Science, Communication and Technology (I JARSCT). 2025;5(4):688.
22. Kumar M, Sul SS, Lakhara JS, Kashid PJ, Bhinge SR, Waghmode AS, Khadake SB. Small Wind Electric System Energy Saver. International Journal of Advanced Research in Science, Communication and Technology (I JARSCT). 2025 May;5(5):447–466.
23. Mulani AO, Bang AV, Birajadar GB, Deshmukh AB, Jadhav HM, Liyakat KK. IoT Based Air, Water, and Soil Monitoring System for Pomegranate Farming. Ann Agri-Bio Res. 2024;29(2): 71–86.
24. Liyakat KK, Khadake SB, Tamboli DA, Sawant VA, HM M, Sathe S. AI-Driven-IoT (AIIoT) Based Decision-Making-KSK Approach in Drones for Climate Change Study. In2024 4th International Conference on Ubiquitous Computing and Intelligent Information Systems (ICUIS) 2024 Dec 12 (pp. 1735–1744). IEEE.
25. Kazi KS. AI-Driven IoT (AIIoT)-Based Decision-Making System for High BP Patient Healthcare Monitoring: KSK1 Approach for BP Patient Healthcare Monitoring. InOptimization, Machine Learning, and Fuzzy Logic: Theory, Algorithms, and Applications 2025 (pp. 71–102). IGI Global Scientific Publishing.
26. Mulani AO, Liyakat KK, Warade NS, Patil A, Kolte MT, Kinage K, Rana M, Salunkhe SS, Jadhav VS, Nagrale M. WITHDRAWN–Administrative Duplicate Publication: ML-powered Internet of Medical Things Structure for Heart Disease Prediction. J Pharmacol Pharmacother. 2025;0(0). doi:10.1177/0976500X241306184.
27. Nerkar PM, Dhaware BU, Liyakat KS. Predictive data analytics framework based on heart healthcare system (HHS) using machine learning. J Adv Zool. 2023;44(2): 3673–3686.
28. Kazi KS. KK Approach for IoT Security: T-Cell Concept. InDeep Learning Innovations for Securing Critical Infrastructures 2025 (pp. 367–388). IGI Global Scientific Publishing.
29. Dubey PK, Singh B, Kumar V, Dubey AK. Application of Wireless, 5G, 6G, and IoT Technologies. In: AI-aided IoT Technologies and Applications in the Smart Business and Production. CRC Press, Taylor & Francis Group; 2023 Dec. ISBN: 9781003392224. Available from: https://doi.org/10.1201/9781003392224.
30. Dubey PK, Singh B, Singh D, Dubey AK. Green Internet of Things. In: Network Optimization in Intelligent IoTs Applications. CRC Press, Taylor & Francis Group; 2023. ISBN: 9781003405535. Available from: https://doi.org/10.1201/9781003405535-8.

