

# AI-DRIVEN FAULT DETECTION AND DIAGNOSTICS

Kahkasha Ahmed<sup>1</sup>, Sonam<sup>2</sup>, Nisha<sup>3</sup>, Puneet Garg<sup>4</sup>

<sup>1,2,3</sup>SAITM Gurugram, Delhi NCR, India

<sup>4</sup>KIET (Deemed to be University), Delhi NCR, Ghaziabad, India

kahkasha.ahmed@gmail.com, kishorisonam95@gmail.com, Nisha\_253184@saitm.ac.in,  
puneetgarg.research@gmail.com

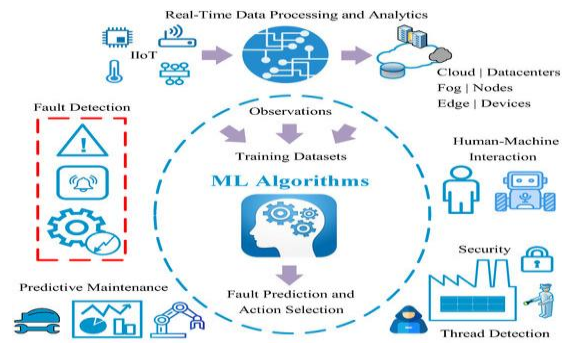
**Abstract:** Artificial intelligence (AI) has changed the game when it comes to fault detection and diagnosis (FDD) because with AI, identifying and solving faults in machines, systems, and networks becomes easy and effective. Manual techniques have traditionally been used to perform these tasks; however, they are tedious and costly. Utilizing the concept of FDD using AI involves a lot of machine learning (ML), deep learning (DL), and data analysis techniques in order to detect and predict possible faults. The sensors continuously, in real time, parse enormous amounts of data, and automated AI readily identifies equipment errors, especially in manufacturing, healthcare, energy, automotive, cybersecurity, and other industries, where error prevention averts failure, enhances safety, and reduces expenses. AI-based systems help organisations optimise machine performance while reducing downtime. AI has the potential to reduce faults through the use of smart algorithms and Internet of Things (IoT) devices. It is important to note that concerns remain regarding data quality, high costs, and the interpretability of AI decisions. With the advancement in AI. The technology, reliability, and usability of AI are improving over time, and fault detection and diagnostics are becoming faster and more effective. This chapter provides a comprehensive review of the applications of artificial intelligence for fault detection and diagnosis, with a critical analysis of the advantages, challenges, and future scope of AI in this domain for improved system performance.

**Keyword:** Artificial Intelligence, Internet of Things (IoT), fault detection and diagnosis (FDD), smart algorithms, machine learning (ML), deep learning (DL)

## 1. INTRODUCTION

In order to ensure high performance and reliable operation in the event of component failures, the Fault defect and diagnosis is important for modern control systems. In the field of system engineering, maintaining the reliability and effectiveness of a complex system is a significant issue [2]. Failure of a system will lead to security concerns in industries such as manufacturing, finance, loss and manufacturing industry, electric power, aerospace, and transportation. Industrial sectors operate through the use of sophisticated machinery along with commands. However, unexpected breakdown will cause damage to the organization in terms of costly system downtime, reduction in efficiency, and even pose potential security risks. Fault detection and diagnostic (FDD) traditionally employs manual checks (along with manpower) combined with predefined thresholds, which ignores the early warning sign of a fault. Traditional techniques of fault diagnosis and detection are tedious, laborious and cannot manage large amount of data, especially in real-time applications [3]. With the ever-increasing complexity of industrial systems, there is need for an intelligent solution. Solutions for maintenance in this regard involve the identification of a potential failure before any detrimental effect, therefore increasing system uptime and saving costs in terms of maintenance.

Artificial Intelligence (AI) has played an important role in the realm of fault diagnosis and detection. Fault Detection and Diagnostics (FDD) using AI involves utilizing ML and DL algorithms to analyze defects to derive insights from large passages of data collected by sensors. This offers a significant improvement over conventional monitoring, enabling real-time operations monitoring at reduced operating cost as per Figure 1 [4].



**Figure 1** AI/ML in fault detection and prevention [10]

The first one is automated anomaly Detection where AI FDD has an ability to continuously analyze big data streams and identify any abnormal and even illegal patterns with no involvement of humans. Such a capability also makes it possible to pre-emptively diagnose minor deviations from specific operating conditions before developing into major problems leading to failure. The AI will also make predictive maintenance viable since the algorithm can predict the probability of failures through analysis of historical and real-time data. This way industries will be able to shift from a reactive maintenance strategy to a proactive maintenance strategy. Thus helping minimize machine downtime and decrease lifespan. [5] The other vital aspect is decision-making based on data using AI-driven FDD. Unlike rule-based systems which depend on static thresholds artificial intelligence systems have a dynamic nature and continuously improve through learning of previous breakdowns and making better diagnoses overtime. This way, industries will be able to develop strategies based on data-based decisions and maintenance schedules. Moreover, the use of AI will reduce cost through reduction of manual routine checking and unpredictable repairs. Dealing with the initial problem in the system becomes cheaper than dealing with a disaster. Therefore, the use of AI-based mistake detection systems leads to increased efficiency, safety, and cost savings compared to the previous incurred costs [6]. Through the use of AI-based FDD, industries can boost their productivity, safety, and maintenance. The current chapter explores the fundamental principles behind the use of AI-based FDD, applications, benefits, and future prospects. The application of AI in combination with fault detection and diagnostics has attracted a lot of interest amongst researchers due to the wide range of benefits it has [4], [10], [16], [21].

### 1.1 Motivation

In modern industries, large quantities of operational data are produced using sensors and other equipment. Conventional approaches to fault identification usually involve inspection procedures and rule-based monitoring; however, these techniques have proven inefficient for identifying more complicated faults. The need for intelligent fault diagnosis systems to identify faults at the earliest stages has emerged in light of growing complexity in modern industrial systems. In this regard, artificial intelligence offers significant potential in the improvement of fault detection accuracy, reduce downtime, enhance operational efficiency, and increase system reliability [4], [10], [16], [21].

### 1.2 Main Contributions

This paper makes the following contributions:

1. It provides an overall review of AI-based Fault Detection & Diagnostics (FDD).
2. It elaborates on the different types of artificial intelligence such as Machine Learning, Deep Learning, Reinforcement Learning, and Hybrid methods applied to fault detection. It examines the applications of AI-based FDD across manufacturing, healthcare, transportation, energy, and other industrial domains.
3. It highlights the benefits, challenges, and future prospects associated with the adoption of AI-driven fault diagnosis systems.

4. It provides a consolidated review of recent developments in intelligent fault detection technologies.

### 1.3 Organization of the Paper

The remainder of this paper is organized as follows. Section 2 discusses the literature review related to AI-based fault detection and diagnostics. Section 3 explains different types of faults and their impact on system performance. Section 4 presents the fundamental concepts of fault detection and diagnostics. Section 5 discusses various AI techniques employed in FDD systems. Section 6 describes major application areas of AI-driven FDD. Section 7 highlights the benefits, challenges, and future prospects of AI-based fault diagnosis systems. Finally, Section 8 concludes the paper and outlines future research directions.

## 2. LITERATURE REVIEW

Artificial Intelligence has become a strong tool that facilitates the process of Fault Detection and Diagnosis (FDD). Many recent works prove that AI techniques provide better results in terms of improved fault detection, diagnostics, and even predictive maintenance, reducing downtime and cutting costs for maintenance [4], [10], [21]. The use of machine learning techniques for intelligent fault diagnosis has been well-studied. The application of machine learning makes fault diagnosis more effective since such techniques allow finding patterns in huge amounts of data. This approach can contribute to successful anomaly detection and predictive maintenance [4], [8], [10], [21]. Hybrid methods have also been studied recently as an important area in the field of fault diagnosis. These methods combine two approaches – model-based and data-driven – thus making the fault diagnostics process more effective [6], [10], [21]. Reinforcement learning has been investigated recently as another approach for developing fault diagnosis systems that can be used as adaptive fault diagnosis systems to enhance decision making and control in dynamic systems [2], [13].

The use of sensor fusion strategies is another method that can be used to increase the efficiency of fault diagnosis systems. This type of strategies relies on the information coming from different sensors and/or data sources to improve fault diagnosis accuracy and reliability [9], [10]. AI-based FDD has been successfully implemented in many areas such as manufacturing industries, medical and healthcare services, transportation, energy systems, and smart infrastructures [17], [18], [19], [20]. Despite all the advancements that have been made in developing intelligent fault diagnosis solutions, some technical barriers remain challenging in this field. Research efforts in this regard seek to overcome such barriers through new approaches and technologies such as edge computing, explainable AI, and hybrid models [4], [10], [21].

## 3. METHODOLOGY

### 3.1 Definition and Types of Faults

A fault in the system is any event or condition that is either unplanned for or would interrupt the normal working state of the system. These faults a system may fail to meet the predefined SLA causing dissatisfaction amongst the users. Reasons could vary from system hardware failure to software bugs or even network problems. Explanation on each of the three sub points:

#### 3.1.1 Hardware Defect

Hardware failure is where the tangible parts of the infrastructure have ceased to function and caused failure. These can be due to excessive usage, harsh surroundings or defects in the creation of the component. Such like include:

- **Failures of the disks:** Blocked HDD or SSD resultant device crashing causing a lack of data or corruption.
- **Outage of power:** shutting off electricity to the region.
- **Processor or memory errors:** calculation errors stem from overheating, defects, or misconfiguration.

**Effect of Hardware Defects:**

- Low system availability.
- Increase in delay due to retreat or reproaching.
- If backups are insufficient then the loss of significant data.

**3.1.2 Software Anomalies**

Software errors and system software or middleware has some logical error or bug in the easiest sense. This may include.

- **Memory leaks:** systemic tiredness of system memory due to improper deals.
- **Application accidents:** unexpected termination of procedures without exception or runtime errors.

**Impact of software anomalies:**

- Downtime or decline of application performance.
- Increase in resource consumption, leading to high operational costs.
- Difficulty pinching and improving the root cause without advanced equipment.

**3.1.3 Network Issues**

Communication channel interruption might cause network failure which may cause problems to hardware, software or environmental issues. Some include:

- Delay Spikes: Increased Delay in Data Transmission.
- Packet loss: Data packets were dropped due to congestion or hardware failure.
- Connection drops: Stopping or full loss of connectivity between nodes.

**Effect of network issues:**

- Delay in data transfer, slowing the workflow.
- Failure of systems distributed to synchronize effectively.
- The inaccessibility of important services for end-users.

**3.2 Impact of Faults on Data Availability and System Performance**

The presence of cloud system defects automatically makes good data hard to reach or increases the time for the whole system to work. The following point was analyzed:

**1. Availability of data**

Defects interfere with the system's ease to retrieve data, especially when they are needed:

- **Services are interrupted:** When other applications or databases try to help a user, they may fail to meet their expectations.
- **Corrupting data:** 'Through the looking glass' hardware or software duplicates data and creates inconsistencies or loss.
- **Compromising backup:** an out of action method for use can result from procedures of setting up systems

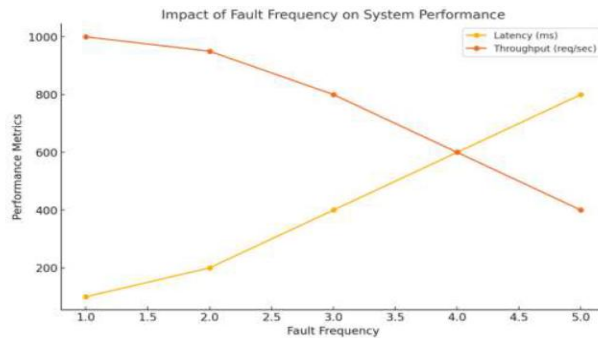
**2. System Performance**

Faults degrade system performance by:

- **Increasing Latency:** Defects make systems reroute processes or retry operations, adding delays
- **Resource Overload:** Faults such as memory leak cause dull usage of resources
- **Operational Downtime:** The critical service may go down, impacting user experience as well as revenue [7].

### Graph: Impact of Faults on System Performance

The below is a graph showing the correlation between fault frequency and system performance attributes such as latency and throughput as per the figure 2



**Figure 2** Graph: Impact of Faults on System Performance [7]

The graph above demonstrates that as the frequency of faults increases:

- Latency (response time) rises significantly, reflecting reduced efficiency.
- Throughput (number of successful requests) drops, indicating reduced system capacity.

And by identifying faults, organizations can make use effective tools, such as advanced A, to build the right systems and minimize risks. [7].

## 4.RESULT AND DISCUSSION

Many systems engines, bearings, among others, undergo phenomenal changes in their performance which can't be measured under normal specification performance condition. Conventional techniques mainly rely on rules-based systems, pre-defined limits, and human follow, making them lengthy and uncertain. Nonetheless, AI-driven FDD takes these traditional methods to the next level by incorporating intelligent and adaptive techniques for better detection accuracy and reliability

### Key components of AI-based FDD include:

#### Pattern Recognition:

- AI models scour historical data sets to determine trends and correlations to equipment failures.
- these models are able to identify early indicators of failure, allowing preventive action before the defects become vital.
- Unlike traditional methods, AI continuously updates based on the upcoming data, improving its pattern recognition for complex defects by reducing false positives. [8][141][142][143][144][145][146][147][148][149][150].

#### Anomaly Detection:

- Real time data of machine is fed to machine learning algorithms to catch remote features and mark deviation from original working condition sensor data.
- Unsupervised learning models like clustering and autoencoders have the capability to recognize the slight differences that are indicative of impending failure.

- Consequently, industries may be able to detect problems before they become issues, thus ensuring that they do not degrade their machinery, minimize the need for maintenance and reduce risks [5].

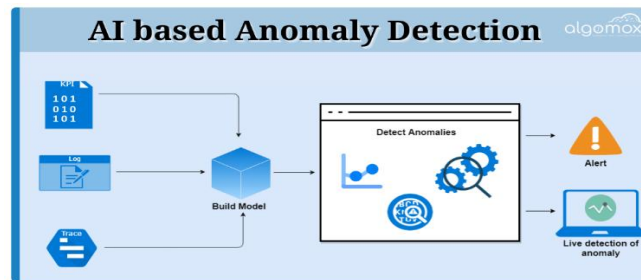


Figure 3 AI based Anomaly Detection [11]

#### Predictive Analytics:

- Historical information, fresh real time information, Artificial intelligence-enabled predictive analysis to calculate probabilities for the particular system breakdown.
- Identifying crucial occurrences or images as semi-automatic with the help of artificial intelligence and labelling them helps in developing competitive and aesthetic designs in order to play a smart game.
- These predictions allow maintenance personnel to be prepared ahead of time, helping in managing assets and reducing downtime.

#### Sensor Fusion:

- AI combines information obtained from different sensors in order to increase accuracy of the fault detection.
- The fusion of information obtained from sensors increases sensitivity of detection due to composite signals detected by the system, which could not have been achieved by any single sensor.
- In real time information fusion allows improving perception and analysis of operational status, which leads to successful functioning and accurate diagnostics [9][130][131][132][133][134][135][136][137][138][139][140].

#### Fault Classification:

- The intelligent classification models classify defects according to predefined classifications depending upon their severity and consequences.
- Scientific approaches such as Neural Networks and Support Vector Machines are applied to distinguish between insignificant problems and the significant problem.
- Fault classification is vital in order to ensure that appropriate actions are taken while focusing on urgent maintenance work.

#### Root Cause Analysis:

- These AI-based diagnostics not only detect faults, but also identify the root cause of failures.
- Causal inference techniques and knowledge-based systems facilitate tracing faults to their source, improving troubleshooting efficiency.
- Drawing root because analysis helps prevent repetitive failure by determining the root cause of equipment failure.

Using these filters made it possible to automate FDD monitoring systems in industries with greater sophistication and reliability. Using this system, organizations gain increased uptime assurance and reduced costs with continuous operation of the necessary systems.

## 5. AI Techniques in Fault Detection and Diagnostics

### 5.1 Machine Learning Algorithms:

Another branch of AI, which is known as Machine Learning (ML), enables such computers to analyze their data and make conclusions or predictions without being programmed to do so. It relies on algorithms that have been designed specifically for certain tasks to increase efficiency.

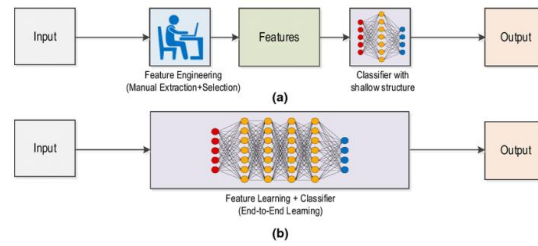
#### Machine Learning Algorithms in Fault Detection and Diagnostics (FDD)

Automating Fault Detection and Diagnostics (FDD) becomes critically important to observe the condition and efficiency of industrial facilities, mechanisms, and electronic equipment. The application of machine learning (ML)-based fault detection and diagnostics technology outperforms traditional FDD due to improved performance and reduced false alarms.

- **Decision tree:** Used for a phased classification of defects dependent on sensors, allowing the recovery of structured and understandable data to detect mistakes.
- **Support Vector Machine (SVM):** For identifying the presence or absence of defects in a system, especially for complex and comprehensive information.
- **Random Forest:** At the same time, two or more decisions connect trees to improve accuracy after the strategy of learning attire.
- **K-Nearest Neighbor (K-Nn):** Useful to detect discrepancy, the mistake already existing with the new information with the new information detects the faults.
- **Nave Bayes:** A potential classifier is useful in diagnosing defects in complex systems where the data is uncertain or incomplete.
- **Gradient Boosting Machines (GBM):** This includes Xgboost and LightGBM that enhance the accuracy of mistake identity by improving predictions.
- **Artificial Neural Networks (ANNS):** Use logic behavior that simulate human learning strategies to search for fault patterns in data related to defects.

### 5.2 Deep Learning Approaches

- **Convolutional Neural Networks (CNNs):** They are used to detect defects through images in industrial machinery, such as cracks, corrosion, or deformity of mechanical parts. They detect and classify images by recognizing important characteristics and discrepancies with high precision. [14][108][109][110][111][112][113][114][115][116][117][118][119][120][121][122][123][124][125][126][127][128][129]
- **Recurrent Neural Networks (RNNs):** RNN sequential sensors are useful for analysis and identity that can identify machine behavior that can suggest malfunction. They are particularly useful in the diagnosis of rotating machinery, HVAC system and power grid control
- **Autoencoders** These particular neural networks learn general operating behavior of a system and detect discrepancies in the form of deviations from learned patterns. They are useful in unwanted fault detection applications where labelled fault data are limited or unavailable
- **Long Short-Term Memory (LSTM) Networks:** LSTMS, a type of RNN, is designed to process sequential data and the future -staging maintenance and initial mistake are very helpful for identification. They are perfect to identify the decline of a slow system before failure as they can simulate long-term dependence in time-series data as per figure 4.



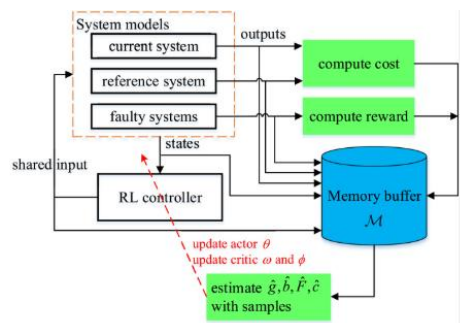
**Figure 4** conventional intelligent fault diagnosis (a) and (b) deep learning based fault diagnosis [12]

### 5.3 Reinforcement Learning

Reinforcement Learning (RL) helps in intelligent decision-making in fault detection and diagnostics (FDD) within unexpected and highly variable industrial environment. Contrary to supervised learning, RL does not require the previous-specified label data, but learns by interacting with the system and optimizing strategies through rewards and punishment.

- **Optimal Maintenance Strategies:** AI operated RL models constantly interact with the system environment, develop strategy for maintenance scheduling and operational activity aimed at reducing productivity and reducing time.
- **Adaptive Fault Diagnosis:** RL founded systems enhance decision-making processes by adjusting to changing industrial conditions in real-time which increases the accuracy of fault detection and response time to anomalies
- **Markov Decision Processes (MDPs):** Quite a number of RL based FDD systems use MDP to model cases of decision making where actions taken now have effects on future system states and is applicable to planned predictive maintenance.
- **Deep Q-Networks (DQN) and Policy Gradient Methods:** These more sophisticated approaches to learn reinforcement increase the future maintenance through exploration and exploitation to detect optimal mistakes

[15][86][87][88][89][90][91][92][93][94][95][96][97][98][99][100][101][102][103][104][105][106][107]



**Figure 5** Reinforcement Learning for FDD[13]

### 5.4 Data-Driven and Hybrid Approaches

Hybrid AI approach integrates machine learning and engineering to detect mistake and increase diagnosis efficiency. These approaches use both insights from machine learning and models from the physical system for increased accuracy and reliability. [21]

- **Sensor Fusion Techniques:** The integration of numerous sensors, along with the use of AI-based fusion models, drastically improves accuracy in fault detection. This technique also increases system flexibility by reducing false positive rates.
- **Hybrid AI-Physics-Based Modelling:** As a result of the inclusion of traditional engineering techniques with machine learning models, the hybrid approach achieves more reliable mistakes by capturing both the dynamics and complex engineer patterns of the physical system and the complex engineer patterns get more reliable mistakes.
- **Bayesian Networks:** These probabilistic models are optimal for both fault analysis and uncertainty ranging in an industrial setting. Bayesian networks model the cause-effect relationships with conditional probabilities and determine the chances of faults occurring under different operational conditions.
- **Digital Twin Technology:** With the aid of Artificial Intelligence, Digital Twin technology simulates an actual system and its surroundings, [16][71][72][73][74][75][76][77][78][79][80][81][82][83][84][85] allowing for real-time data such as proper maintenance, anomaly detection, as well as fault analysis without physical failures actually occurring. As per figure 6

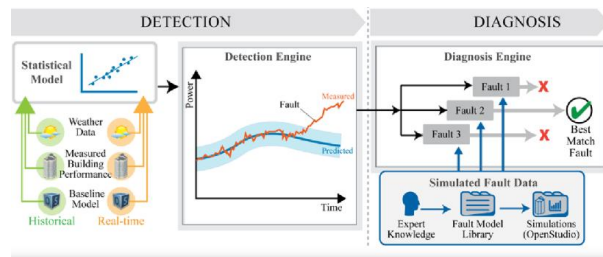


Figure 6 Hybrid Approaches for FDD

## 6. Applications of AI-Driven FDD

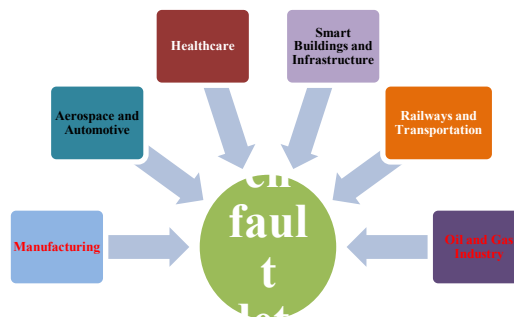


Figure 7 Applications of AI-Driven FDD

AI- Many industries in detecting and diagnosis of driven defects have extensive applications:

1. **Manufacturing:** In industrial applications, AI-managed future maintenance is added to industrial machinery to prevent unpredictable rupture, thus to monitor failure and initial mistake. AI sensor data

helps in minimization, productivity optimization, and overall equipment effectiveness (OEE) growth in downtime

[18][49][50][51][52][53][54][55][56][57][58][59][60][61][62][63][64][65][66][67][68][69][70]

2. **Aerospace and Automotive:** FDD systems are used to implement predictive diagnostics within aircraft and automobile engines. Having AI detect faults within sensor systems and construction parts enables early fault detection which furthers safety, reduces expensive repairs, and increases the scope of critical components.
3. **Energy Sector:** Power station, wind turbine, and solar panel monitoring are constantly checked using AI technology to ensure failure-proof operation and avoid complete system failures. Outage detection during energy distribution and using the power grid predictive analytics improves the grid's reliability while reducing outages [19][22][23][24][25][26][27][28][29][30].
4. **Healthcare:** Medical equipment such as MRI, ventilator, and C scanners have fault detection systems integrated to ensure that malfunctions do not affect patients. AI automatically increases equipment reliability through timely maintenance ensuring operational risks in a hospital are minimal [17][31][32][33][34][35][36][37][38][39][40].
5. **Smart Buildings and Infrastructure:** AI-based FDD applies in HVAC (heating, ventilation, and air conditioning) systems, electrical grids and structural monitoring of buildings. These systems detect discrepancies in temperature control, power distribution and material stress, improve security and reduce energy consumption.
6. **Railways and Transportation:** AI-Interested Diagnostics play an important role in monitoring railway infrastructure, to prevent accidents and optimize the maintenance schedule, detect and optimize defects in tracks, signals and rolling stocks and optimize the maintenance program [19][41][42][43][44][45][46][47][48][49].
7. **Oil and Gas Industry:** AI-based FDD is used to identify rust, leaks and mechanical defects in pipelines, drilling equipment and refinery operations, compliance with safety rules and to reduce environmental threats.
8. **Telecommunications:** detecting AI-powered mistake helps monitor the network infrastructure, identifying issues such as signal fall, hardware failures and threats of cyber security, leading to improve better service credibility and downtime.

## 7. Benefits of AI in Fault Detection and Diagnostics

Integration of AI in FDD provides many benefits:

- **Increased Accuracy:** AI FDD discovers for corrosion, leaks and mechanical defects in the application, drilling rigs, and refinement in refinery operations, helping in compliance with safety rules, reducing environmental hazards and preventive maintenance.
- **Real-Time Monitoring:** AI-based fault detection is used to monitor the network infrastructure for issues such as hardware failure or degradation of signals and cybersecurity, resulting in increased service reliability and minimum downtimes.
- **Cost Reduction:** AI systems reduce false positive and false negative rates during fault diagnosis, resulting in more accuracy in diagnostic outcomes.
- **Extended Equipment Life:** Monitoring with a quick response of defects for monitoring continuous system and reducing problems quickly.
- **Enhanced Decision-Making:** AI-based Insights provide data-driven recommendations to operators that increase strategic planning and operational efficiency.
- **Reduced Human Intervention:** By automating many processes involved in diagnosing a problem, the AI-managed FDD can reduce human error by reducing the role of humans in the process.
- **Facilitation of Energy Efficiency:** AI enhances energy consumption management by optimizing equipment deployment and detecting faults.

- **Safety Improvement:** AI enables immediate measures taken to avoid any hazardous condition as it recognizes faults in early detection, contributing to a safe workforce as well as adherence to the required safety regulations.

## 8. Challenges and Future Prospects of AI-Driven FDD

AI-based FDD certainly has advantages; however, some of its limitations include:

- **High-Quality Data:** It requires high-quality data and availability of diverse and labelled datasets for the construction of an accurate AI algorithm.
- **High Computing Power:** This is not any software, but rather computing that consumes substantial processing power and requires certain expertise in the matter.
- **Legacy System:** Some industries use traditional approaches for fault detection and therefore make it difficult to incorporate the AI system in their operation.
- **False Positives:** AI-based fault detection can create a lot of confusion as far as identifying faults and can lead to over fitting issues as well.
- **Security Issues:** There is an inherent security risk present in the system, and therefore there is a need for robust security mechanisms.

### Future Prospects:

- **Explainable AI (XAI):** Improvement in XAI technology will develop trustworthiness in such technology that will further facilitate its adoption in important industries in our society.
- **Real-Time Analysis via Edge Computing** – Localization of FDD latencies within cloud computing architecture
- **Sensor Technologies:** Upgraded sensor technology will provide improved data inputs which further improve diagnostics.
- **AI-Based Self-healing Technology:** In the future, with the help of advanced models, future systems can become self-healing and minimize the need for downtime.
- **Global Standards and Regulations:** Future global regulations and standards for safe AI will facilitate the adoption of AI technology for FDD purposes..

## 9. CONCLUSION

AI-powered Fault Detection and Diagnosis (FDD) systems have revolutionized how organizations detect, diagnose, and manage faults in systems. The use of Machine Learning, Deep Learning, Reinforcement Learning, and Hybrid techniques in an AI-based FDD system ensures efficient fault detection, predictive maintenance, real-time diagnostics, and increased efficiency. Application of these advanced intelligent systems has proven highly beneficial in various sectors like manufacturing, healthcare, transport, energy, telecoms, and smart infrastructure.

However, while there are benefits in applying intelligent systems in these industries, issues related to quality of data, computational complexities, integration, security concerns, and explainability remain a challenge. But with ongoing developments in Explainable AI, digital twins, sensor fusion, edge computing, and self-healing, most of these challenges could be overcome.

### 9.1 Limitations

- This paper uses the secondary data available in the existing literature.
- There was no experiment performed to test the efficacy of any algorithm.
- Performance comparison between various AI models has not been made.
- The success of the AI model depends on the industry or operational environment.

## 9.2 Future Scope

- Research in Explainable AI (XAI) to provide transparency for fault diagnosis.
- Combining the technology of Digital Twin with AI-driven predictive maintenance systems.
- Edge computing for real-time fault detection and identification.
- Research in developing autonomous self-healing systems that can fix faults on their own.
- Improvements in sensor fusion algorithms for better fault detection in complex conditions.

## CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this research.

## REFERENCES

- [1] Garg, P., Dixit, A., & Sethi, P. (2022). MI-fresh: novel routing protocol in opportunistic networks using machine learning. *Computer Systems Science & Engineering, Forthcoming*. Tech Science Press.
- [2] Yadav, P. S., Khan, S., Singh, Y. V., Garg, P., & Singh, R. S. (2022). A Lightweight Deep Learning-Based Approach for Jazz Music Generation in MIDI Format. *Computational Intelligence and Neuroscience, 2022*.
- [3] Soni, E., Nagpal, A., Garg, P., & Pinheiro, P. R. (2022). Assessment of Compressed and Decompressed ECG Databases for Telecardiology Applying a Convolution Neural Network. *Electronics, 11(17), 2708*.
- [4] Pustokhina, I. V., Pustokhin, D. A., Lydia, E. L., Garg, P., Kadian, A., & Shankar, K. (2021). Hyperparameter search based convolution neural network with Bi-LSTM model for intrusion detection system in multimedia big data environment. *Multimedia Tools and Applications, 1-18*.
- [5] Khanna, A., Rani, P., Garg, P., Singh, P. K., & Khamparia, A. (2021). An Enhanced Crow Search Inspired Feature Selection Technique for Intrusion Detection Based Wireless Network System. *Wireless Personal Communications, 1-18*.
- [6] Garg, P., Dixit, A., Sethi, P., & Pinheiro, P. R. (2020). Impact of node density on the qos parameters of routing protocols in opportunistic networks for smart spaces. *Mobile Information Systems, 2020*.
- [7] Upadhyay, D., Garg, P., Aldossary, S. M., Shafi, J., & Kumar, S. (2023). A Linear Quadratic Regression-Based Synchronised Health Monitoring System (SHMS) for IoT Applications. *Electronics, 12(2), 309*.
- [8] Saini, P., Nagpal, B., Garg, P., & Kumar, S. (2023). CNN-BI-LSTM-CYP: A deep learning approach for sugarcane yield prediction. *Sustainable Energy Technologies and Assessments, 57, 103263*.
- [9] Saini, P., Nagpal, B., Garg, P., & Kumar, S. (2023). Evaluation of Remote Sensing and Meteorological parameters for Yield Prediction of Sugarcane (*Saccharum officinarum* L.) Crop. *Brazilian Archives of Biology and Technology, 66, e23220781*.

- [10] Beniwal, S., Saini, U., Garg, P., & Joon, R. K. (2021). Improving performance during camera surveillance by integration of edge detection in IoT system. *International Journal of E-Health and Medical Communications (IJEHMC)*, 12(5), 84-96.
- [11] Garg, P., Dixit, A., & Sethi, P. (2019). Wireless sensor networks: an insight review. *International Journal of Advanced Science and Technology*, 28(15), 612-627.
- [12] Sharma, N., & Garg, P. (2022). Ant colony based optimization model for QoS-Based task scheduling in cloud computing environment. *Measurement: Sensors*, 100531.
- [13] Kumar, P., Kumar, R., & Garg, P. (2020). Hybrid Crowd Cloud Routing Protocol For Wireless Sensor Networks. *International Journal of Advanced Science and Technology*, 29, 766-775.
- [14] Raj, G., Verma, A., Dalal, P., Shukla, A. K., & Garg, P. (2023). Performance Comparison of Several LPWAN Technologies for Energy Constrained IOT Network. *International Journal of Intelligent Systems and Applications in Engineering*, 11(1s), 150-158.
- [15] Garg, P., Sharma, N., & Shukla, B. (2023). Predicting the Risk of Cardiovascular Diseases using Machine Learning Techniques. *International Journal of Intelligent Systems and Applications in Engineering*, 11(2s), 165-173.
- [16] Patil, S. C., Mane, D. A., Singh, M., Garg, P., Desai, A. B., & Rawat, D. (2024). Parkinson's Disease Progression Prediction Using Longitudinal Imaging Data and Grey Wolf Optimizer-Based Feature Selection. *International Journal of Intelligent Systems and Applications in Engineering*, 12(3s), 441-451.
- [17] Gudur, A., Pati, P., Garg, P., & Sharma, N. (2024). Radiomics Feature Selection for Lung Cancer Subtyping and Prognosis Prediction: A Comparative Study of Ant Colony Optimization and Simulated Annealing. *International Journal of Intelligent Systems and Applications in Engineering*, 12(3s), 553-565.
- [18] Khan, A. (2024). Optimisation Methods Based on Soft Computing for Improving Power System Stability. *J. Electrical Systems*, 20(6s), 1051-1058.
- [19] Sharma, K. K., Verma, P. K., & Garg, P. (2024). IoT-Enabled Energy Management Systems For Sustainable Energy Storage: Design, Optimization, And Future Directions. *Frontiers in Health Informatics*, 13(8).
- [20] Gupta, S., Yadav, N., Singh, K., & Garg, P. (2025). APPLICATIONS OF SIMULATIONS AND QUEUING THEORY IN SUPERMARKET. *Reliability: Theory & Applications*, 20(1 (82)), 135-140.
- [21] Beniwal, S., Garg, P., Rajpal, R., Sharma, N., & Mittal, H. K. (2025). Fusion of Opportunistic Networks with Machine Learning: Present and Future. *Metallurgical and Materials Engineering*, 31(1), 311-324.
- [22] Garg, P. (2025). Explainable AI & Model Interpretability in Healthcare: Challenges & Future Directions. *EKSPLORIUM-BULETIN PUSAT TEKNOLOGI BAHAN GALIAN NUKLIR*, 46(1), 104-133.
- [23] Rani, P. (2025). From Data to Diagnosis: Unleashing AI and 6G in Modern Medicine. *EKSPLORIUM-BULETIN PUSAT TEKNOLOGI BAHAN GALIAN NUKLIR*, 46(1), 69-103.
- [24] Dixit, A., Garg, P., Sethi, P., & Singh, Y. (2020, April). TVCCCS: Television Viewer's Channel Cost Calculation System On Per Second Usage. In *IOP Conference Series: Materials Science and Engineering* (Vol. 804, No. 1, p. 012046). IOP Publishing.
- [25] Sethi, P., Garg, P., Dixit, A., & Singh, Y. (2020, April). Smart number cruncher—a voice based calculator. In *IOP Conference Series: Materials Science and Engineering* (Vol. 804, No. 1, p. 012041). IOP Publishing.

- [26] S. Rai, V. Choubey, Suryansh and P. Garg, "A Systematic Review of Encryption and Keylogging for Computer System Security," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 157-163, doi: 10.1109/CCiCT56684.2022.00039.
- [27] L. Saraswat, L. Mohanty, P. Garg and S. Lamba, "Plant Disease Identification Using Plant Images," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 79-82, doi: 10.1109/CCiCT56684.2022.00026.
- [28] L. Mohanty, L. Saraswat, P. Garg and S. Lamba, "Recommender Systems in E-Commerce," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 114-119, doi: 10.1109/CCiCT56684.2022.00032.
- [29] C. Maggo and P. Garg, "From linguistic features to their extractions: Understanding the semantics of a concept," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 427-431, doi: 10.1109/CCiCT56684.2022.00082.
- [30] N. Puri, P. Sagggar, A. Kaur and P. Garg, "Application of ensemble Machine Learning models for phishing detection on web networks," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 296-303, doi: 10.1109/CCiCT56684.2022.00062.
- [31] R. Sharma, S. Gupta and P. Garg, "Model for Predicting Cardiac Health using Deep Learning Classifier," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 25-30, doi: 10.1109/CCiCT56684.2022.00017.
- [32] Varshney, S. Lamba and P. Garg, "A Comprehensive Survey on Event Analysis Using Deep Learning," *2022 Fifth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, 2022, pp. 146-150, doi: 10.1109/CCiCT56684.2022.00037.
- [33] Dixit, A., Sethi, P., Garg, P., & Pruthi, J. (2022, December). Speech Difficulties and Clarification: A Systematic Review. In *2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART)* (pp. 52-56). IEEE.
- [34] Garg, P., Dixit, A., Sethi, P., & Pruthi, J. (2023, December). Strengthening Smart City with Opportunistic Networks: An Insight. In *2023 International Conference on Advanced Computing & Communication Technologies (ICACCTech)* (pp. 700-707). IEEE.
- [35] Rana, S., Chaudhary, R., Gupta, M., & Garg, P. (2023, December). Exploring Different Techniques for Emotion Detection Through Face Recognition. In *2023 International Conference on Advanced Computing & Communication Technologies (ICACCTech)* (pp. 779-786). IEEE.
- [36] Mittal, K., Srivastava, K., Gupta, M., & Garg, P. (2023, December). Exploration of Different Techniques on Heart Disease Prediction. In *2023 International Conference on Advanced Computing & Communication Technologies (ICACCTech)* (pp. 758-764). IEEE.
- [37] Gautam, V. K., Gupta, S., & Garg, P. (2024, March). Automatic Irrigation System using IoT. In *2024 International Conference on Automation and Computation (AUTOCOM)* (pp. 100-103). IEEE.
- [38] Ramasamy, L. K., Khan, F., Joghee, S., Dempere, J., & Garg, P. (2024, March). Forecast of Students' Mental Health Combining an Artificial Intelligence Technique and Fuzzy Inference System. In *2024 International Conference on Automation and Computation (AUTOCOM)* (pp. 85-90). IEEE.

- [39] Rajput, R., Sukumar, V., Patnaik, P., Garg, P., & Ranjan, M. (2024, March). The Cognitive Analysis for an Approach to Neuroscience. In *2024 International Conference on Automation and Computation (AUTOCOM)* (pp. 524-528). IEEE.
- [40] Dixit, A., Sethi, P., Garg, P., Pruthi, J., & Chauhan, R. (2024, July). CNN based lip-reading system for visual input: A review. In *AIP Conference Proceedings* (Vol. 3121, No. 1). AIP Publishing.
- [41] Bose, D., Arora, B., Srivastava, A. K., & Garg, P. (2024, May). A Computer Vision Based Framework for Posture Analysis and Performance Prediction in Athletes. In *2024 International Conference on Communication, Computer Sciences and Engineering (IC3SE)* (pp. 942-947). IEEE.
- [42] Singh, M., Garg, P., Srivastava, S., & Saggi, A. K. (2024, April). Revolutionizing Arrhythmia Classification: Unleashing the Power of Machine Learning and Data Amplification for Precision Healthcare. In *2024 Sixth International Conference on Computational Intelligence and Communication Technologies (CCICT)* (pp. 516-522). IEEE.
- [43] Kumar, R., Das, R., Garg, P., & Pandita, N. (2024, April). Duplicate Node Detection Method for Wireless Sensors. In *2024 Sixth International Conference on Computational Intelligence and Communication Technologies (CCICT)* (pp. 512-515). IEEE.
- [44] Bhardwaj, H., Das, R., Garg, P., & Kumar, R. (2024, April). Handwritten Text Recognition Using Deep Learning. In *2024 Sixth International Conference on Computational Intelligence and Communication Technologies (CCICT)* (pp. 506-511). IEEE.
- [45] Gill, A., Jain, D., Sharma, J., Kumar, A., & Garg, P. (2024, May). Deep learning approach for facial identification for online transactions. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 715-722). IEEE.
- [46] Mittal, H. K., Dalal, P., Garg, P., & Joon, R. (2024, May). Forecasting Pollution Trends: Comparing Linear, Logistic Regression, and Neural Networks. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 411-419). IEEE.
- [47] Malik, T., Nandal, V., & Garg, P. (2024, May). Deep Learning-Based Classification of Diabetic Retinopathy: Leveraging the Power of VGG-19. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 645-651). IEEE.
- [48] Srivastava, A. K., Verma, I., & Garg, P. (2024, May). Improvements in Recommendation Systems Using Graph Neural Networks. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 668-672). IEEE.
- [49] Aggarwal, A., Jain, D., Gupta, A., & Garg, P. (2024, May). Analysis and Prediction of Churn and Retention Rate of Customers in Telecom Industry Using Logistic Regression. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 723-727). IEEE.
- [50] Mittal, H. K., Arsalan, M., & Garg, P. (2024, May). A Novel Deep Learning Model for Effective Story Point Estimation in Agile Software Development. In *2024 International Conference on Emerging Innovations and Advanced Computing (INNOCOMP)* (pp. 404-410). IEEE.
- [51] Shukla, S. M., Magoo, C., & Garg, P. (2024, November). Comparing Fine Tuned-LMs for Detecting LLM-Generated Text. In *2024 3rd Edition of IEEE Delhi Section Flagship Conference (DELCON)* (pp. 1-8). IEEE.
- [52] Kumar, B., IQBAL, M., Parmer, R., Garg, P., Rani, S., & Agrawal, A. (2025, March). The Role of AI in Optimizing Healthcare Appointment Scheduling. In *2025 3rd International Conference on Disruptive Technologies (ICDT)* (pp. 881-887). IEEE.

- [53] Kumar, B., Garg, V., Ahmed, K., Garg, P., Choudhary, S., & Baniya, P. (2025, March). Enhancing Healthcare with Blockchain: Innovations in Data Privacy, Security, and Interoperability. In *2025 3rd International Conference on Disruptive Technologies (ICDT)* (pp. 932-938). IEEE.
- [54] Raj, V., Prakash, B. K., Kumar, A., & Garg, P. (2024, December). Optimize the Time a Mercedes-Benz Spends on the Test Bench Using Stacking Ensemble Learning. In *2024 International Conference on Progressive Innovations in Intelligent Systems and Data Science (ICPIDS)* (pp. 445-450). IEEE.
- [55] Kaushik, N., Kumar, H., Raj, V., & Garg, P. (2024, December). Proactive Fault Prediction in Microservices Applications Using Trace Logs and Monitoring Metrics. In *2024 International Conference on Progressive Innovations in Intelligent Systems and Data Science (ICPIDS)* (pp. 410-415). IEEE.
- [56] Kumar, A. A., Sri, C. V., Bohara, K. S. K., Setia, S., & Garg, P. (2024, December). Capnivesh: Financing Platform for Startups. In *2024 International Conference on Progressive Innovations in Intelligent Systems and Data Science (ICPIDS)* (pp. 261-265). IEEE.
- [57] Bhandari, P., Setia, S., Kumar, K., & Garg, P. (2024, December). Optimizing Cross-Platform Development with CI/CD and Containerization: A Review. In *2024 International Conference on Progressive Innovations in Intelligent Systems and Data Science (ICPIDS)* (pp. 175-180). IEEE.
- [58] Chaudhary, A., & Garg, P. (2014). Detecting and diagnosing a disease by patient monitoring system. *International Journal of Mechanical Engineering And Information Technology*, 2(6), 493-499.
- [59] Malik, K., Raheja, N., & Garg, P. (2011). Enhanced FP-growth algorithm. *International Journal of Computational Engineering and Management*, 12, 54-56.
- [60] Garg, P., Dixit, A., & Sethi, P. (2021, May). Link Prediction Techniques for Opportunistic Networks using Machine Learning. In *Proceedings of the International Conference on Innovative Computing & Communication (ICICC)*.
- [61] Garg, P., Dixit, A., & Sethi, P. (2021, April). Opportunistic networks: Protocols, applications & simulation trends. In *Proceedings of the International Conference on Innovative Computing & Communication (ICICC)*.
- [62] Garg, P., Dixit, A., & Sethi, P. (2021). Performance comparison of fresh and spray & wait protocol through one simulator. *IT in Industry*, 9(2).
- [63] Malik, M., Singh, Y., Garg, P., & Gupta, S. (2020). Deep Learning in Healthcare system. *International Journal of Grid and Distributed Computing*, 13(2), 469-468.
- [64] Gupta, M., Garg, P., Gupta, S., & Joon, R. (2020). A Novel Approach for Malicious Node Detection in Cluster-Head Gateway Switching Routing in Mobile Ad Hoc Networks. *International Journal of Future Generation Communication and Networking*, 13(4), 99-111.
- [65] Gupta, A., Garg, P., & Sonal, Y. S. (2020). Edge Detection Based 3D Biometric System for Security of Web-Based Payment and Task Management Application. *International Journal of Grid and Distributed Computing*, 13(1), 2064-2076.
- [66] Garg, P., & Raman, P. K. (2011). Broadcasting Protocol & Routing Characteristics With Wireless ad-hoc networks. *Int. J. Comput. Emg. Manag*, 12(1), 36-40.
- [67] Garg, P., Arora, N., & Malik, T. (2011). Capacity Improvement of WI-MAX In presence of Different Codes WI-MAX: Speed & Scope of fu-ture. *IJCEM*, 12.

- [68] Garg, P., Saroha, K., & Lochab, R. (2011). Review of wireless sensor networks-architecture and applications. *IJCSMS International Journal of Computer Science & Management Studies*, 11(01), 2231-5268.
- [69] Yadav, S., & Garg, P. Development of a New Secure Algorithm for Encryption and Decryption of Images.
- [70] Dixit, A., Sethi, P., & Garg, P. (2022). Rakshak: A Child Identification Software for Recognizing Missing Children Using Machine Learning-Based Speech Clarification. *International Journal of Knowledge-Based Organizations (IJKBO)*, 12(3), 1-15.
- [71] Shukla, N., Garg, P., & Singh, M. (2022). MANET Proactive and Reactive Routing Protocols: A Comparison Study. *International Journal of Knowledge-Based Organizations (IJKBO)*, 12(3), 1-14.
- [72] Arya, A., Garg, P., Vellanki, S., Latha, M., Khan, M. A., & Chhbra, G. (2024). Optimisation Methods Based on Soft Computing for Improving Power System Stability. *Journal of Electrical Systems*, 20(6s), 1051-1058.
- [73] Garg, P. (2025). Cloud security posture management: Tools and techniques. *Technix International Journal for Engineering Research*, 12(3).
- [74] Tyagi, P., Sharma, S., Srivastava, A., Rajput, N. K., Garg, P., & Kumari, M. (2025). AI in Healthcare: Transforming Medicine with Intelligence. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p4>
- [75] Garg, P., Bhatt, M., Parmar, R., & Arsalan, M. (2025). Generative AI: Evolution, Applications, Challenges And Future Prospects. *Applications, Challenges And Future Prospects (May 17, 2025)*.
- [76] Garg, P., Saraswat, P., & Siddiqui, Z. (2025). AI & the Indian Stock Market: A Review of Applications in Investment Decision. <https://doi.org/10.63169/GCARED2025.p10>
- [77] Garg, P., Sharma, S., Mittal, S., Tevatia, R., Tyagi, V. K., & Kapoor, S. (2025). Unlocking Workforce Potential: AI-Powered Predictive Models for Employee Performance Evaluation. <https://doi.org/10.63169/GCARED2025.p21>
- [78] Shrivias, N., Kalia, A., Roy, R., Sharma, S., Garg, P., & Agarwal, G. (2025). OSINT: A Double-edged Sword. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p22>
- [79] Garg, P., Aditi, A., & Roy, B. (2025). A System of Computer Network: Based On Artificial Intelligence. <https://doi.org/10.63169/GCARED2025.p24>
- [80] Parmar, R., Kapoor, S., Saifi, S., & Garg, P. (2025). Case Study on Intelligent Factory Systems for Improving Productivity and Capability in Industry 4.0 with Generative AI. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p28>
- [81] Singh, R., Sharma, R., Kumar, R., Nafis, A., Siddiqui, M. A. M., & Garg, P. (2025). Detection of Unauthorized Construction using Machine Learning: A Review. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p30>
- [82] Garg, P., Kapoor, S., Singh, V., Sharma, S., & Ankita, A. (2025). A Bridge between Blockchain and Decentralized Applications Web3 and Non-Web3 Crypto Wallets. <https://doi.org/10.63169/GCARED2025.p35>
- [83] Verma, M., Sharma, S., Garg, P., & Singh, A. (2025). The Hidden Dangers of Prototype Pollution: A Comprehensive Detection Framework. In *First Global Conference on AI*

- Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p36>
- [84] Sharma, A., Sharma, S., Garg, P., & Bhardwaj, P. (2025). LockTalk: A Basic Secure Chat Application. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India.
- [85] Arora, K., Bawane, R., Gupta, C., Ahmed, K., & Garg, P. (2025). Detection and Prevention of Cyber Attack and Threat using AI. In *First Global Conference on AI Research and Emerging Developments (G-CARED 2025)*, New Delhi, India. <https://doi.org/10.63169/GCARED2025.p38>
- [86] Garg, P., Dhruv, D., Rahman, A. A., Rai, A., Siddiqui, M., & Yadav, D. (2025). Easeviewer: An Esports Production Tool. <https://doi.org/10.63169/GCARED2025.p46>
- [87] Garg, P., Lakshita, L., Mehwish, M., Nazia, N., & Ahmed, K. (2025). Emerging Trend in Computational Technology: Innovations, Applications, and Challenges. *Applications, and Challenges (May 17, 2025)*. <https://doi.org/10.63169/GCARED2025.p51>
- [88] Chauhan, S., Singh, M., & Garg, P. (2021). Rapid Forecasting of Pandemic Outbreak Using Machine Learning. *Enabling Healthcare 4.0 for Pandemics: A Roadmap Using AI, Machine Learning, IoT and Cognitive Technologies*, 59-73.
- [89] Gupta, S., & Garg, P. (2021). An insight review on multimedia forensics technology. *Cyber Crime and Forensic Computing: Modern Principles, Practices, and Algorithms*, 11, 27.
- [90] Shrivastava, P., Agarwal, P., Sharma, K., & Garg, P. (2021). Data leakage detection in Wi-Fi networks. *Cyber Crime and Forensic Computing: Modern Principles, Practices, and Algorithms*, 11, 215.
- [91] Meenakshi, P. G., & Shrivastava, P. (2021). Machine learning for mobile malware analysis. *Cyber Crime and Forensic Computing: Modern Principles, Practices, and Algorithms*, 11, 151.
- [92] Nanwal, J., Garg, P., Sethi, P., & Dixit, A. (2021). Green IoT and Big Data: Succeeding towards Building Smart Cities. In *Green Internet of Things for Smart Cities* (pp. 83-98). CRC Press.
- [93] Gupta, M., Garg, P., & Agarwal, P. (2021). Ant Colony Optimization Technique in Soft Computational Data Research for NP-Hard Problems. In *Artificial Intelligence for a Sustainable Industry 4.0* (pp. 197-211). Springer, Cham.
- [94] Magoo, C., & Garg, P. (2021). Machine Learning Adversarial Attacks: A Survey Beyond. *Machine Learning Techniques and Analytics for Cloud Security*, 271-291.
- [95] Garg, P., Srivastava, A. K., Anas, A., Gupta, B., & Mishra, C. (2023). Pneumonia Detection Through X-Ray Images Using Convolution Neural Network. In *Advancements in Bio-Medical Image Processing and Authentication in Telemedicine* (pp. 201-218). IGI Global.
- [96] Gupta, S., & Garg, P. (2023). 14 Code-based post-quantum cryptographic technique: digital signature. *Quantum-Safe Cryptography Algorithms and Approaches: Impacts of Quantum Computing on Cybersecurity*, 193.
- [97] Prakash, A., Avasthi, S., Kumari, P., & Rawat, M. (2023). PuneetGarg 18 Modern healthcare system: unveiling the possibility of quantum computing in medical and biomedical zones. *Quantum-Safe Cryptography Algorithms and Approaches: Impacts of Quantum Computing on Cybersecurity*, 249.
- [98] Gupta, S., & Garg, P. (2024). Mobile Edge Computing for Decentralized Systems. *Decentralized Systems and Distributed Computing*, 75-88.

- [99] Gupta, M., Garg, P., & Malik, C. (2024). Ensemble learning-based analysis of perinatal disorders in women. In *Artificial Intelligence and Machine Learning for Women's Health Issues* (pp. 91-105). Academic Press.
- [100] Malik, M., Garg, P., & Malik, C. (2024). Artificial intelligence-based prediction of health risks among women during menopause. *Artificial Intelligence and Machine Learning for Women's Health Issues*, 137-150.
- [101] Garg, P. (2024). Prediction of female pregnancy complication using artificial intelligence. In *Artificial Intelligence and Machine Learning for Women's Health Issues* (pp. 17-35). Academic Press.
- [102] Pokhrel, L., Arsalan, M., Rani, P., Garg, P., & Pinheiro, P. R. (2026). AI-Powered Healthcare Solutions: Bridging the Medical Gap in Underserved Communities Worldwide. In *Applied AI and Computational Intelligence in Diagnostics and Decision-Making* (pp. 57-86). IGI Global Scientific Publishing.
- [103] Kapoor, S., Parmar, R., Sharma, N., Garg, P., & Singh, N. J. (2026). AI and Computational Intelligence in Healthcare: An Introductory Guide. In *Applied AI and Computational Intelligence in Diagnostics and Decision-Making* (pp. 1-26). IGI Global Scientific Publishing.
- [104] Pokhrel, L., Kumar, A., Garg, P., Anand, N., & Singh, N. (2026). AI and IoT in Global Health: Ethical Lessons From Pandemic Response. In *Development and Management of Eco-Conscious IoT Medical Devices* (pp. 367-394). IGI Global Scientific Publishing.
- [105] Parmar, R., Singh, A., Garg, P., Sharma, T., & Pinheiro, P. R. (2026). Blockchain for Ethical Supply Chains: Transparency in Medical IoT Manufacturing. In *Development and Management of Eco-Conscious IoT Medical Devices* (pp. 337-366). IGI Global Scientific Publishing.
- [106] Gupta, S., Garg, P., Agarwal, J., Thakur, H. K., & Yadav, S. P. (2024). Federated learning based intelligent systems to handle issues and challenges in IoVs (Part 1). <https://doi.org/10.2174/97898153130311240301>
- [107] Gupta, S., Chaudhary, G., & Garg, P. (2013). Modified AODV Routing Protocol through Cache Memory for Finding New Routing Paths in MANETs. *International Journal of Computer Science & Management Studies*, 13(3).
- [108] Gupta, A., & Garg, P. (2021). Emerging Techniques for Handling Pandemic Challenges. *Enabling Healthcare 4.0 for Pandemics: A Roadmap Using AI, Machine Learning, IoT and Cognitive Technologies*, 189-209.
- [109] Chaudhary, A. P., Mishra, A., Kumar, D., & Garg, P. (2023, April). Human Emotion Recognition using Deep Learning. In *2023 International Conference on Computational Intelligence, Communication Technology and Networking (CICTN)* (pp. 191-197). IEEE.
- [110] Nagpal, S., Garg, P., Gaba, S., & Aggarwal, A. (2023). 13 An improved genetic quantum cryptography model for network communication. *Quantum-Safe Cryptography Algorithms and Approaches: Impacts of Quantum Computing on Cybersecurity*, 177.
- [111] Yadav, M., Swami, V., Kumar, N., & Garg, P. (2025). Comparative study of Repairable Juice Plants using RPGT. *Reliability: Theory & Applications*, 20(2 (84)), 776-783.
- [112] Gupta, A., Garg, P., & Yadav, P. (2025). Role of Generative AI Towards Education and Learning: Present & Future. *TPM-Testing, Psychometrics, Methodology in Applied Psychology*, 32(S6 (2025): Posted 15 Sept), 1059-1076.
- [113] Dalal, P., Beniwal, G., Sharma, V., Garg, P., & Ahmed, K. (2025). Predicting Student Motivation and Engagement through Machine Learning Models. *TPM-Testing, Psychometrics, Methodology in Applied Psychology*, 32(S7 (2025): Posted 10 October), 393-411.

- [114] Gupta, A., Mund, A., Roy, S., Garg, P., & Yadav, D. K. (2025). Trust in AI Systems: A Social-psychological Investigation of Human–AI Collaboration. *TPM–Testing, Psychometrics, Methodology in Applied Psychology*, 32(S7 (2025): Posted 10 October), 428-446.
- [115] Bhardwaj, A., Das, A., Garg, P., & Yadav, S. (2025). Material-Driven Performance Analysis of a Vertical Nanowire Tunnel FET for Analog Applications: Bhardwaj, Das, Garg, and Yadav. *Journal of Electronic Materials*, 1-12.
- [116] Dalal, P., Sharma, B., Sharma, T., Garg, P., & Ahmed, K. (2025). Explainable AI for Understanding Human Decision Making Patterns. *TPM–Testing, Psychometrics, Methodology in Applied Psychology*, 32(S7 (2025): Posted 10 October), 412-427.
- [117] Sharma, K. K., Verma, P. K., Garg, P., & Shrotriya, V. K. (2025, October). Predicting costs and benefits of IoT-based energy management for optimizing sustainable energy storage in rural areas. In *AIP Conference Proceedings* (Vol. 3343, No. 1, p. 040017). AIP Publishing LLC.
- [118] Ahmed, K., Baranwal, A., Sharma, N., Garg, P., & Singh, N. (2026). The Role of Federated Learning in AI-Powered Integrated Healthcare Solutions. In *Enabling Collaborative Health Intelligence With Federated Learning* (pp. 421-448). IGI Global Scientific Publishing.
- [119] Gupta, S., Garg, P., Agarwal, J., Thakur, H. K., & Yadav, S. P. (2025). Federated learning based intelligent systems to handle issues and challenges in IoVs (Part 2). Bentham Science Publishers. <https://doi.org/10.2174/97898153222241250301>
- [120] Garg, P., Pranav, S., & Prerna, A. (2021). Green internet of things (G-IoT): A solution for sustainable technological development. In *Green Internet of Things for Smart Cities* (pp. 23-46). CRC Press.
- [121] Malik, A., Nandal, D., Gupta, V., Garg, P., & Nandal, V. INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING.
- [122] Gupta, S., Garg, P., Agarwal, J., Thakur, H. K., & Yadav, S. P. (Eds.). (2025). Federated learning based intelligent systems to handle issues and challenges in IoVs (Part 2).
- [123] Garg, P., Bhatt, M., Parmar, R., & Arsalan, M. (2025). Generative AI: Evolution, Applications, Challenges And Future Prospects. *Applications, Challenges And Future Prospects (May 17, 2025)*.
- [124] Kumar, N., Kumar, Y., Khurana, D., Kumar, S., & Garg, P. (2025, November). A Hybrid Ensemble Learning Framework for Interpretable Student Performance Prediction Using Academic and Extracurricular Factors. In *2025 International Conference on Innovations and Emerging Technologies In AI & Communication Systems (IETACS)* (pp. 666-672). IEEE.
- [125] Khurana, D., Kumar, Y., Kumar, N., Kumar, S., & Garg, P. (2025, November). Transformer-Based Movie Recommendation System with Autoencoder-Enhanced Feature Compression. In *2025 International Conference on Innovations and Emerging Technologies In AI & Communication Systems (IETACS)* (pp. 685-690). IEEE.
- [126] Garg, P. (2025, November). Comparative Analysis of Various Neural Networks for Galaxies Classification. In *2025 International Conference on Innovations and Emerging Technologies In AI & Communication Systems (IETACS)* (pp. 697-701). IEEE.
- [127] Saggi, A. K., Babbar, N., & Garg, P. (2025, November). Health-Guard AI: Integrated Health Report Management and Analysis. In *2025 International Conference on Innovations and Emerging Technologies In AI & Communication Systems (IETACS)* (pp. 614-623). IEEE.
- [128] Kumar, S., Kumar, Y., Kumar, N., Khurana, D., & Garg, P. (2025, November). Hybrid FCM-DNN Model for Uncertainty-Aware Air Quality Classification Using Multi-Pollutant Data.

- In *2025 International Conference on Innovations and Emerging Technologies In AI & Communication Systems (IETACS)* (pp. 679-684). IEEE.
- [129] Babbar, N., Singh, H. V., Bendale, S., & Garg, P. (2025, November). Stock Market Price Prediction Using Big Data Analysis: A Performance Evaluation Study. In *2025 3rd International Conference on Computational Intelligence and Network Systems (CINS)* (pp. 1-6). IEEE.
- [130] Singh, A. K., Kori, G., Garg, P., & Srivastava, G. (2025, November). Bank Churn Prediction Using Machine Learning. In *2025 IEEE 7th International Conference on Computing, Communication and Automation (ICCCA)* (pp. 1-6). IEEE.
- [131] Bhardwaj, A., Das, A., Garg, P., & Yadav, S. (2026). Material-Driven Performance Analysis of a Vertical Nanowire Tunnel FET for Analog Applications. *Journal of Electronic Materials*, 55(1), 1099-1110.
- [132] Srivastava, A. K., Shankdhar, D., Ror, R., & Garg, P. (2026). Harnessing YOLOv5 for real-time object detection: A cloud-based approach. In *Recent Advances in Computational Methods in Science and Technology* (pp. 441-450). CRC Press.
- [133] Srivastava, A. K., Shukla, A., Gupta, H., Saxena, K., & Garg, P. (2026). Towards intelligent attendance management system with face recognition using LBPH algorithm. In *Recent Advances in Computational Methods in Science and Technology* (pp. 8-15). CRC Press.
- [134] Srivastava, A. K., Garg, P., & Pandey, H. (2026). Vedcure: Towards intelligent ayurvedic drug recommendation and disease prediction. In *Recent Advances in Computational Methods in Science and Technology* (pp. 16-23). CRC Press.
- [135] Upadhyay, D., Garg, P., & Babbar, N. (2026). Blockchain and IoT based smart contract framework for efficient and secure product life management. *Discover Internet of Things*.
- [136] Singh, A., Parmar, R., Bhardwaj, P., Sharma, V., & Garg, P. (2026). Fusion of Aerial Networks with Advanced Computing Paradigms. *Edge Computing and Aerial Platforms*, 355-367.
- [137] Kumari, M., Baranwal, A., Sonal, & Garg, P. (2026). Application of Aerial Edge Computing in Disaster Management. *Edge Computing and Aerial Platforms*, 103-122.
- [138] Aditi, Saraswat, P., Sharma, V., & Garg, P. (2026). Advances in Aerial Platforms and Edge Computing. *Edge Computing and Aerial Platforms*, 123-143.
- [139] Garg, P., Arora, K., Bawane, R., Gupta, C., & Ahmed, K. (2025). Detection and Prevention of Cyber Attack and Threat using AI.
- [140] Ahmed, K., Ahmed, A., Khan, J., Garg, P., Seth, S., & Mallik, S. (2025). Principal Component Analysis Based Clustering of Insecticides and Molecular Docking of Pyrethroids Insecticides.
- [141] Kumar, B., Kumar, A., Nanwal, J., Garg, P., & Patnaik, P. (2025, November). Ensemble of YOLOv5 and Segment Anything Model for Brain Tumor Detection. In *2025 2nd International Conference on Advanced Computing and Emerging Technologies (ACET)* (pp. 1-5). IEEE.
- [142] Arsalan, M., Anas, M., & Garg, P. (2025). Transparent AI for Drug Discovery and Development. *Available at SSRN 5844242*.
- [143] Singh, A., Bhardwaj, P., Garg, P., & Singh, N. (2026). Introduction to explainable artificial intelligence in healthcare. In *Explainable AI in Clinical Practice* (pp. 23-44). Academic Press.
- [144] Kapoor, S., Singh, A., Garg, P., & Ramasamy, L. K. (2026). Explainable artificial intelligence in a diagnostic support system. In *Explainable AI in Clinical Practice* (pp. 131-145). Academic Press.

- [145] Ahmed, K., Anas, M., & Garg, P. (2026). Case studies on unlocking the potential of Industry 4.0 for sustainable manufacturing through generative AI-driven innovations. *Available at SSRN 6356958*.
- [146] Garg, P., & Oruganti, S. K. (2026, March). AI Assisted Routing Optimization in Opportunistic IoT Networks using Machine Learning: A Comprehensive review on Protocols & Simulators. In *Sustainable Global Societies Initiative* (Vol. 1, No. 4). Vibrasphere Technologies.
- [147] Arsalan, M., Pokhrel, L., & Garg, P. (2026). Architecture, Components, and tools in Integrated AI-Augmented Intelligence: A design perspective. *Components, and tools in Integrated AI-Augmented Intelligence: A design perspective (March 19, 2026)*.
- [148] Singh, H., Ahmed, K., & Garg, P. (2026). Human Versus Machine Customer Behaviour and Functional Differences. *Available at SSRN 6441098*.
- [149] Saraswat, P., & Garg, P. (2026). Soft Computing in AI Agents.
- [150] Saraswat, P., & Garg, P. (2026). Water Quality Prediction Using IOT Sensors and Deep Networks.