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Dynamic Fault Detection and Recommendation System for IoT-Based Smart Offices

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Abstract

The Internet of Things (IoT) is revolutionizing industry 5.0 by enabling the deployment of sensors across various sectors. However, early fault prediction is crucial for maintaining the integrity, accuracy, reliability, and fidelity of IoT sensor nodes. As data capture by IoT devices increases, cloud computing becomes essential. A proposed model monitors real-time health of IoT devices using a machine learning algorithm, enhancing efficiency and indoor comfort. The model analyzes device and sensor values, transmitting data to the cloud for intelligent fault prediction. The model's performance was evaluated using Decision Tree, KNearest Neighbor, Gaussian Naive Bayes, and Random Forest techniques. The model demonstrated the efficiency of machine learning techniques for predicting faults in IoT-enabled offices, with Random Forest showing the highest accuracy of 94.27%.

Keywords: Internet of things, AI, Deep learning, Machine learning, Information, Smart Offices.

Introduction

The Internet of Things (IoT) is a rapidly growing digital revolution that connects real-world entities to the internet, enabling remote control and interaction with the physical world. IoT is a mix of technology and connectivity, resulting from the interaction between sensors, real-time networks, and data centers. It was invented by Kevin Ashton and is now evolving into a new technological mainstream [1-5].

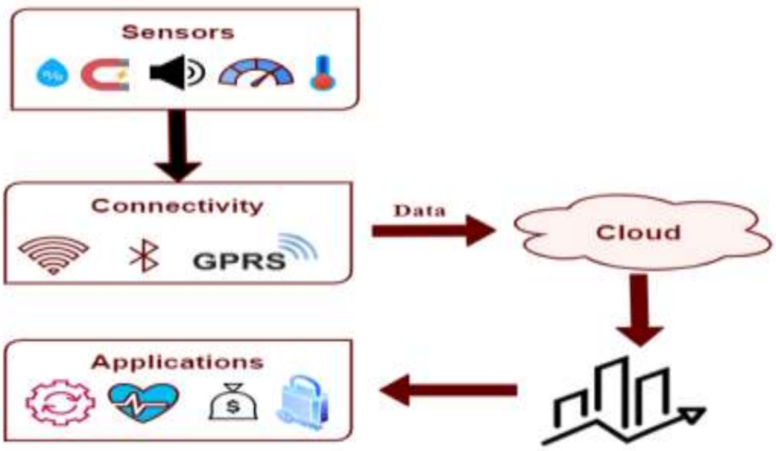

Fig.-1 Block Diagram of Proposed system

IoT defines a network of objects identified distinctively in virtual cyberspace, with embedded sensors, software, and other technologies that communicate and exchange data with other appliances. It processes data and creates techniques incorporating smart technology, Radio

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Frequency Identification (RFID), sensing equipment, and other technology advancements. The automation industry plays a crucial role in economic development, using latest technologies to improve financial competitiveness [6-10].

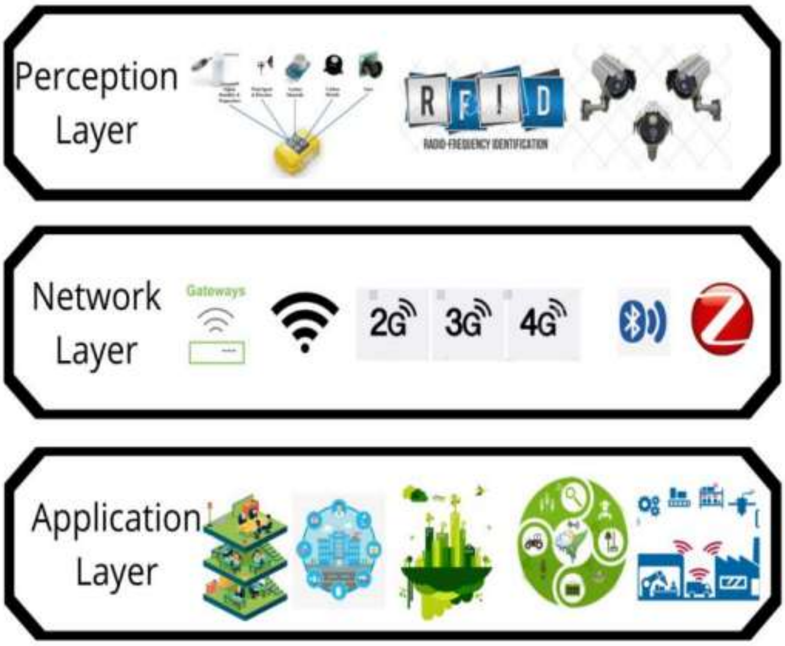

Fig.2 Internet of Things Architecture: Key Layers and Components

IoT-based sensors have been proven to improve work conditions, prevent bugs, diagnose faults, predict quality, and help managers make better decisions. The number of IoT sensing devices is growing, and data generated from these is also growing exponentially. IoT plays an essential role in human life through e-health, smart home, and smart learning [11-15].

Fig.-3 IoT and its application areas

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The global IoT market has reached $9.1 billion, with the Compound Annual Growth Rate rising at a rate of 40% by 2024. IoT architecture must accommodate this growth, with various factors influencing its success, such as handling network issues like addressability, security, scalability, and efficient energy utilization [16-20].

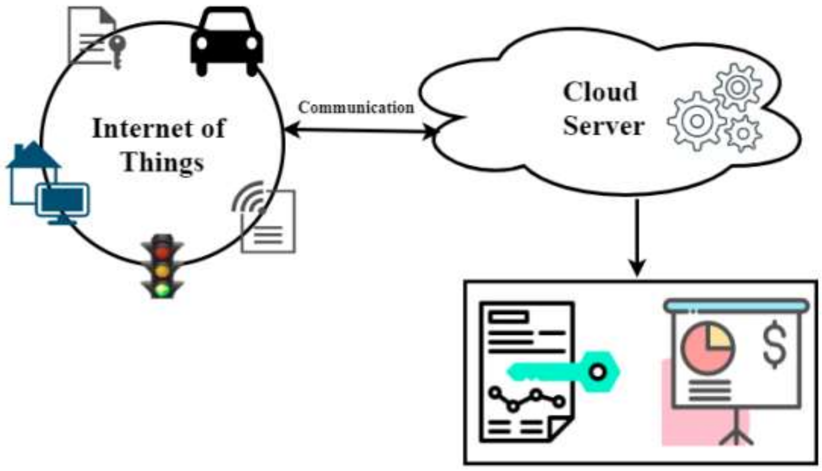

Fig.-4 Integration of IoT with cloud

IoT applications include smart healthcare, smart agriculture, smart traffic systems, smart environment, smart office, smart home, and supply chain logistics. Office automation, or an intellectual office system, provides an assisted working environment for users, enhancing their quality of work [21-25]. However, there are challenges to overcome, such as the complexity of physical entities and the need for robust and high-performance Wireless Sensor Networks (WSNs).

The Internet of Things (IoT) is a rapidly growing technology that is transforming various industries, including production processes, agriculture, and home automation. The increasing demand for digital terminals equipped with robust sensors has led to a greater process of data acquisition modules for Industrial IoT (IIoT). One such application area is the smart office, which monitors the health of IoT equipment using machine learning or deep learning to improve efficiency and indoor comfort. Early fault prediction in real-life devices is crucial for smart offices. Researchers have been interested in predicting sensor faults in IoT data, with most studies focusing on analyzing the type of sensor and identifying patterns in faults. Techniques such as suspension faults, real-time monitoring, data fusion, feedback loops, and transactuations have been proposed to improve fault tolerance in IoT applications. The fall curve technique helps predict faults when faulty readings mimic actual data readings of IoT sensors. A literature review of 63 Scopus indexed papers from 2016 to 2021 was conducted to analyze the literature and draw conclusions [26-30].

The number of papers published in the field of IoT applications has been increasing year by year, with the highest number of papers published in 2020 at a 76.23% annual growth rate. The top eight sources for the most papers are IEEE Internet of Things Journal, IEEE Transactions on Automation Science and Engineering, and Advances in Intelligent Systems and Computing. A literature review on fault prediction based on different machine learning techniques in IoT applications has been conducted. Liu et al. presented a framework for self-learning sensor fault detection, while Vibhute et al. presented a sensor failure prediction model. Cicirelli et al. proposed a meta-model of the smart environment, while Furdik et al. developed a prototype of a smart office system using LinkSmart semantic middleware. Da Xu et al. summarized the state-of-the-art industrial IoT research, introducing service-oriented

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architecture models, basic technologies, and essential applicability. Mundada et al. also contributed to the literature review [31-35].

The Internet of Things (IoT) is revolutionizing industries like production, agriculture, and home automation. The demand for robust sensors has led to increased data acquisition for Industrial IoT (IIoT). The smart office uses machine learning or deep learning to monitor IoT equipment's health, improving efficiency and indoor comfort. Researchers are studying sensor faults in IoT data, using techniques like suspension faults, real-time monitoring, data fusion, feedback loops, and transactuations. A literature review of 63 Scopus indexed papers from 2016 to 2021 analyzed the literature and concluded that fault prediction based on machine learning techniques is crucial for IoT applications.

The proposed fault prediction recommender model (FPRM) for an IoT-enabled office aims to enhance system performance and reduce human intervention. The architecture connects all office appliances using the internet, containing electrical appliances, sensors, and a database server. Data is stored on a non-volatile cloud with excess space for regular retrieval. A web application monitors live data from appliances, allowing the ML algorithm to predict faults and recommend solutions. The end-user can monitor power consumption and predict future faults, preventing damage to appliances. The system comprises four modules: Arduino, Cloud, a web application, electrical appliances, and sensors. Sensors send data to the Arduino IoT Cloud via WiFi, and the internet connection is used to observe, analyze, and predict faults in appliances. The sensors update data continuously and respond to user changes via a web application.

The proposed model consists of an Arduino Mega 2560 Rev3 microcontroller, which performs real-time monitoring of electrical appliances and sensors in an office. The data generated by these devices and sensors is stored in an SD card sent to the cloud via a wifi module. A real-time clock displays data at each instance, while an MP3 player notifies the user about the system's functioning. The proposed fault prediction recommender model (FPRM) for office employees monitors the electric appliances and sensors, saving energy automatically. This model is better than other existing models because it is unit-wise monitored and economical.

The hardware specifications include a 16 x 2 LCD with time and status information, a web application that alerts users about predicted faults, and a ACS712 current sensor with a range of sensitivity and output sensitivity. The system also includes a power supply, LCD, real-time clock, MP3 player, and a smartphone/laptop internet connection. The ESP8266 WiFi module is used for end-point IoT developments, with an integrated TCP/IP protocol stack. The ACS712 current sensor measures current flow within a wire using the concept of the magnetic field, determining energy usage and increasing efficiency. The system also uses an I2C interface for I2C communication.

Result and Analysis

The proposed fault prediction recommender model (FPRM) for an IoT-enabled office aims to improve system performance and reduce human intervention. The system connects all office appliances using the internet, containing electrical appliances, sensors, and a database server. Data is stored on a non-volatile cloud, and a web application monitors live data from appliances. The ML algorithm predicts faults and recommends solutions, allowing end-users to monitor power consumption and prevent damage. The system consists of four modules:

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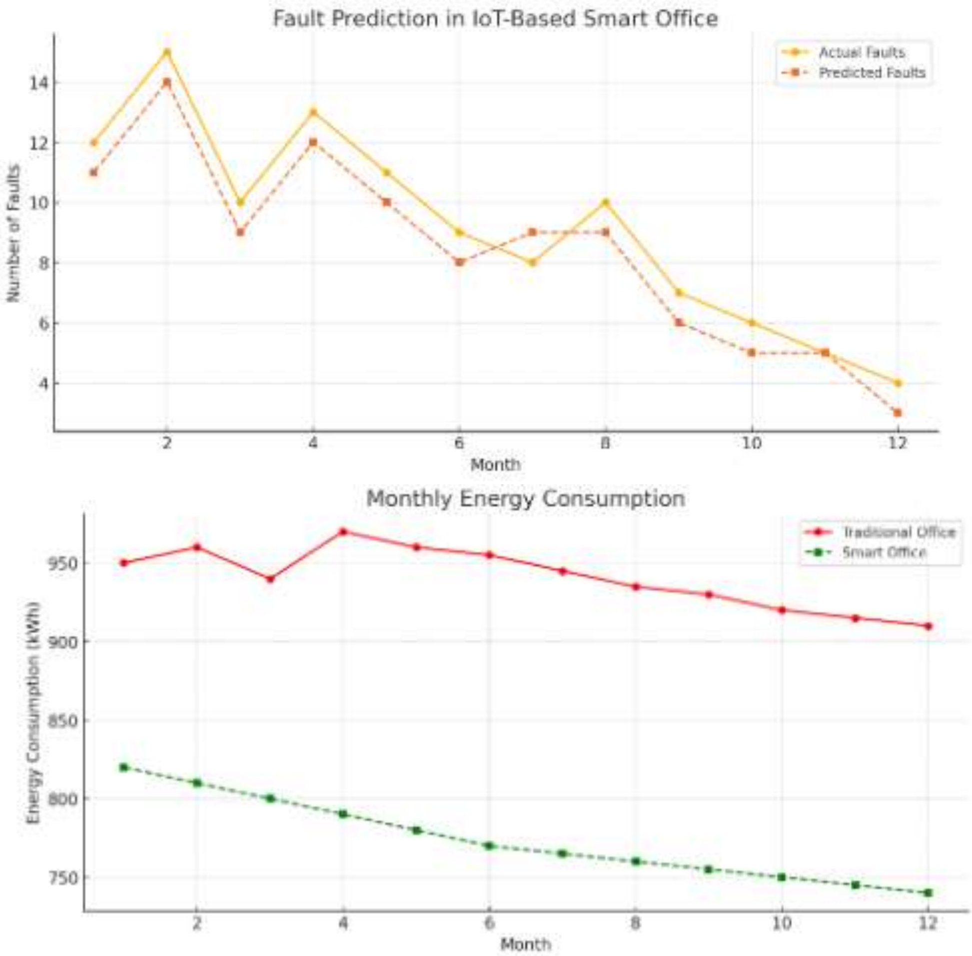

Fig. 5 Overall analysis

Two analysis graphs for an IoT-based smart office are shown here:

- Fault Prediction Accuracy Over Time – Shows how well the system predicts faults compared to actual faults each month.
- Comparison of Monthly Energy Use: Shows that, on average, smart offices use less energy than conventional ones.

Conclusion

The Internet of Things (IoT) is a network of smart physical objects that communicate with each other and the external environment, with applications in transportation, industries, hospitality, agriculture, and healthcare. As the number of IoT-enabled appliances increases, so does the volume of data. A real-time fault prediction recommender model (FPRM) is developed to monitor real-time data of sensor nodes in an office environment, using cloud storage and a machine learning algorithm to predict faults and prevent unexpected casualties. The model monitors data from various devices and sensors, including temperature, humidity, and fire, and sends it to a cloud server for fault prediction using a machine learning

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algorithm. The model alerts users about abnormal conditions and increases safety and comfort by informing them about early fault occurrence. The performance of the proposed model was analyzed through various metrics, with Random Forest performing best with the highest precision, accuracy, and recall. Decision Tree was the least preferable for fault prediction in an office environment. The future scope of this research includes investigating fall curve techniques, statistical evaluation using IoT simulators, expanding fault prediction capabilities to include fault diagnosis, identification, and prognosis, considering data security, and expanding the study to include more connected IoT devices. The proposed fault prediction recommender model uses machine learning for early fault prediction, and deep learning may be applied depending on the dataset size.

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