REAL-TIME SENSOR DATA ANALYTICS AND VISUALIZATION IN CLOUD-BASED SYSTEMS FOR FOREST ENVIRONMENT MONITORING

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Submitted: *Feb, 25, 2023* ***Revised:*** *Apr, 21, 2023* ***Accepted:*** *May, 04, 2023*

Abstract: Forest environment monitoring is essential for natural resource management. The development of sensors using across forests enables for the collection massive volumes of data due to technological improvements in the sensor network. Raspberry Pi, a flexible and inexpensive single-board computer, is at the main of the system, connecting and interfacing with the many sensors spread throughout the system. Sensors such as this can collect crucial information about the forest's environment, such as the weather, humidity, and temperature. Data from various sensors can be acquired and processed in real-time due to Raspberry Pi's role as a data collection device. The system uses cloud-based services to overcome the limitations of on-premises data processing and storage. A fusion technique on the cloud platform combines and analyzes data from various sensors after receiving transmissions from Raspberry Pi. The cloud service provides a location for live monitoring and other visualization which greatly help data in real-time. These visuals can be accessed remotely, allowing users to access the forest from any location. Improved comprehension and control of forest environments are possible because of the combination of various technologies for collecting, analyzing, and evaluating sensor data.

Keywords: Internet of Things, Raspberry Pi, Sensors, Cloud, Remote Monitoring.

I. INTRODUCTION

Due to human activity, forests worldwide are fast declining. In the last several decades, animal attacks in villages, towns, and cities have grown significantly. Illegal human actions like poaching have increased dramatically. Forest rangers can only cover a small region due to a lack of access and equipment [1]. An effective forest monitoring system device will track temperature, humidity, and animal and human entrance and departure. Animals and forest landscapes are thermally imaged using the thermal imaging camera. It will also detect forest fires.

Optimization through the Internet of Things is improving our lives. Industry and logistics improve with smart gadgets. IoT-based frameworks for climate change and environmental monitoring are beneficial [2]. IoT refers to the standard organization of physical objects that use the internet to communicate and provide customer information. In this circumstance, data collection has increased significantly. Limiting and processing this massive amount of data into valuable estimates and evaluation criteria is one of its biggest problems.

Deforestation and natural calamities like forest fires and rising gas emissions harm the forest ecology [3]. The Raspberry Pi Model 3, analog and digital sensors, and signals processing techniques are used to monitor forest environments intelligently. Sensors monitor parameters including temperature, gas concentrations, soil humidity, and more, while background noises are processed by a classification system to classify the created event: Background sounds from a chainsaw, vehicle, or forest. Internet and mobile apps enable users to view the gathered data and get warnings about fires, pollution, and illegal deforestation.

The several environment monitoring systems for diverse reasons are report reviewed. Review analysis and discussion offered important suggestions [4]. Deep learning, massive data, noisy data, and effective categorization frameworks need substantial environments. Smart agricultural systems that address environmental issues have focused on water and air quality monitoring. Embedded system advancements have shown to be a trustworthy answer for managing and keeping tabs on environmental monitoring systems [5]. The ultimate goal is to create a scalable system that anybody can use to keep tabs on any number of environmental variables. Miniaturized sensor devices paired with wireless technology have made remote monitoring feasible.

The world has undergone dramatic transformations because of the advent of IoT technology [6]. Numerous sources attest to the widespread acceptance and promising future of IoT environment monitoring and smart home technologies. With the advent of IoT technology based on the ZIGBEE protocol, we can now investigate a networking-based intelligent platform to monitor our forest environmental elements timely.

Living in the forest has relied heavily on accurate weather reports. There needs to be more data on the temporal and geographical environmental variables that influence forest health at the present moment [7]. Humidity and temperature sensing are the primary foci of this endeavor, which collects environmental information from the forests. The use of a WSN allows for the collection of real-time data from every location in the forest, which is not possible with more conventional methods of meteorological data collection.

It provides a model for early fire detection using the Raspberry Pi microcontroller and the appropriate sensors. Data storage and analysis are performed on a central server [8]. For making forecasts, a neural network with a complete feedback connection is employed. The administrator and nearby residents are then notified through an alert message.

II. LITERATURE REVIEW

Forests provide many living things and wood to breathe; it requires it. However, forest acreage is decreasing annually [9]. Deforestation, forest fires, and illegal activities cause these environmental effects. Wild creatures and human welfare resources may be most at risk from forest fires. Fires start due to forest heat. The dry, hot weather triggered the forest fire. Deforestation and smuggling damage the available forest. In [10] details the planning, implementation, and testing of a wireless sensor network to keep tabs on forests. The necessary multisensory to conceal the forest has been set up. This method will be used in wildlife sanctuaries and zoos in addition to instantly informing forest authorities about fire accidents and animal monitoring. It can also be used to keep tabs on your pet. This method is also excellent for keeping wild animals out of inhabited areas near forests.

The growth, developments, and uses of the IoT in the fire protection sector in [11]. In addition, the report outlines a survey done to identify research trends and obstacles in fire initiatives. The fire IoT aims to connect various fire-related devices with relevant organizations. It details the building and microcontroller-based smoke and temperature detector process that sounds an alert when a fire is detected. This effort aims to develop and deploy an IoT-based system that can operate autonomously, identify and anticipate forest fires, and transmit their precise locations to relevant authorities, assisting firefighting personnel in containing flames closer to their points of origin [12]. As a result, firefighters could contain the blaze in a smaller area and avoid future fires by taking preventative steps.

It comprehensively reviews the signs used to spot and locate forest fires [13]. Also provided are the corresponding communication protocols and AI methods used. In addition, it discusses the advantages and disadvantages of this technique to help future research into the development of early-warning systems for fire detection. It also highlights a review to identify directions and challenges in forest fire management. Global warming raises fire danger mechanically. Forest fires are growing. It describes a forest fire early detection system to help fire troops on the ground [14]. This method is more exact than satellite and lookout tower monitoring. The suggested method uses artificial intelligence, namely Deep Learning models, to forecast forest fires using ambient wireless sensor network data. A system based on the IoT requires a Low Power Wide Area Network, stationary or mobile sensors, and a solid deep learning model. We demonstrated the possibility of an autonomous, real-time environmental tracking platform for dynamic forest fire risk indicators by comparing multiple deep learning models.

Fires destroy millions of hectares of forests globally, destroying human lives, materials, natural flora, animals, and raw resources [15]. Forests with guards or communication systems are better. Thus, many IoT-based forest fire warning systems have been presented recently. The proposed a long-distance forest fire detection system. This system uses Long Range technology based on LoRaWAN protocol to connect low-power devices across large geographical areas. It is an innovative and efficient solution for low data transfer rate transmissions and low transmission power on high ranges.

III. PROPOSED SYSTEM

The system aims to facilitate the sensor data analysis and its subsequent show in real time for forest environmental monitoring. Integrating data from various sensors, processing it in real-time, using data fusion methods, and producing user-friendly visual representations are all goals. The scalability and accessibility of the system are both enabled by its use of cloud-based infrastructure. To improve forest conservation efforts by giving users current data on environmental conditions, allowing for remote monitoring, facilitating informed decision-making, and increasing the potential of successful outcomes.

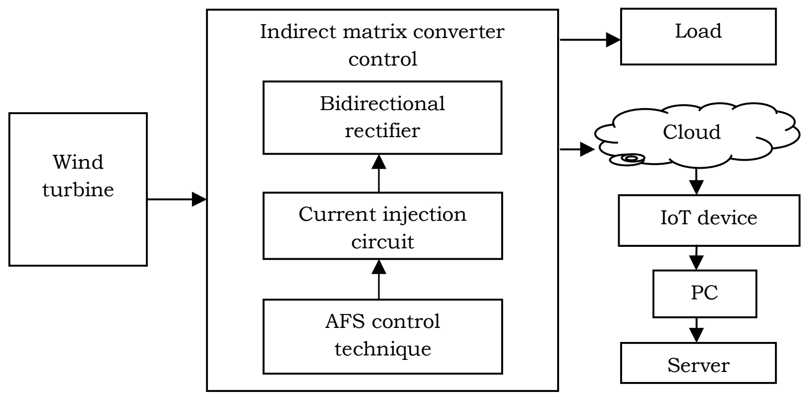

Fig. 1 Converter design and IoT system

The wind turbine generator, indirect matrix converter, AFS control block, IoT-based monitoring block, IoT server, and voltage control output are all shown connected to one another in this block diagram. The suggested technology integrates indirect matrix converter control, accurate voltage management using the AFS method, and real-time grid monitoring via IoT-based technologies. The functionality, effectiveness, and dependability of the WES that are tied to the power grid are improved.

The indirect matrix converter (IMC) now provides an AC supply from the wind energy that may be linked to a bidirectional rectifier. Distributed computing is then used to determine and save the specific parameters according to the amount of work. The IoT service has been connected to a PC and server through closed-loop control, allowing us to see the values of the service's parameters via the web or a mobile device. Designs for the coordination of information progress are made possible by the IoT. Expanding the AFS voltage exchange fraction of the IMC using the PWM technique reduces total harmonic distortion (THD) and boosts output.

The present third harmonic injection is made up of a reaction from the bridge legs, an inductor, and three bidirectional switches. The harmonic current is infused into its associated input stage by switching on only one of all three two-way switches under normal operating circumstances. The VSC's output frequency, amplitude, and phase are all adjustable to meet the needs of the load. When the system is turned off, the power stored in the load's spilling inductance is kept using a clamp circuit. The third-symphony current is maintained by the bidirectional switch connected to the input circuits that have the lowest dominant voltage.

A. Working Principle

Forested areas have temperature and humidity monitors, gas sensors, smoke detectors, and fire alarms. In real time, these sensors monitor environmental parameters, including temperature, humidity, gas concentration, smoke detection, and fire. The data from the sensors is collected and processed by a Raspberry Pi processor. The Raspberry Pi receives the data from the sensors and performs the primary processing, such as calibrating and normalizing the values.

The Raspberry Pi sends its processed sensor data to the cloud platform through any wireless or internet connection. The information is sent in real-time to be analyzed afterward. Data from sensors measuring temperature, humidity, gas levels, smoke, and fire is sent to a cloud platform, and data fusion techniques are used to collect and analyze the information. Several data sources must be fused together to provide an all-encompassing picture of the forest ecosystem.

In the cloud, the data from the integrated sensors may be processed instantly. Statistics and anomaly detection are two examples of advanced analytics methods for identifying abnormal events. Dashboards, visualizations, and connections with the processed data can be viewed in detail. Users can quickly monitor and understand the status of the forest due to the visualizations, which display data from sensors in an approachable and practical style. The cloud's user-friendly interface allows remote forest managers, administration, and governments to utilize the system. From anywhere, it can monitor the live visualizations, be notified of any unusual activity, and learn more about the state of the forest environment.

Users can make informed choices and take corrective measures based on the observed circumstances due to the real-time and visible sensor data. Forest management and environmental activities are enhanced by their ability to react quickly to warnings of fire, gas leaks, and other environmental hazards. Sensor data is continuously collected, processed, and analyzed in real-time on the cloud, shown interactively, and made available remotely. The system offers thorough monitoring and helps reduce dangers in the forest ecosystem by combining humidity, temperature, gas, smoke, or fire sensors.

B. System design

The Sensor measures in for all of the forest's sensors, including those that detect heat, gases, smoke, and fire. These sensors are used to gather information about the environment. The Raspberry Pi is the brains of the operation, collecting and analyzing all of the data. It gathers sensor information, analyses it, and carries out any necessary initial data changes or calibrations before sending it to the cloud service. The Cloud Platform stores data, fuse data, analyze data in real time and displays the results visually. Data is received from the Raspberry Pi and stored safely; data fusion methods combine the sensor data, real-time analysis is performed, and visualizations are generated to provide more insights.

Forest managers are some of the users that may benefit from the interface's interactive dashboards and visualizations. It enables them to keep tabs on the live data, be notified of any dangers (like fires), and act accordingly. Users of the system analyze data in real time, make selections based on that data, and react to changes in the monitored forest environment, all represented by the Forest Monitoring block diagram in Figure 1.

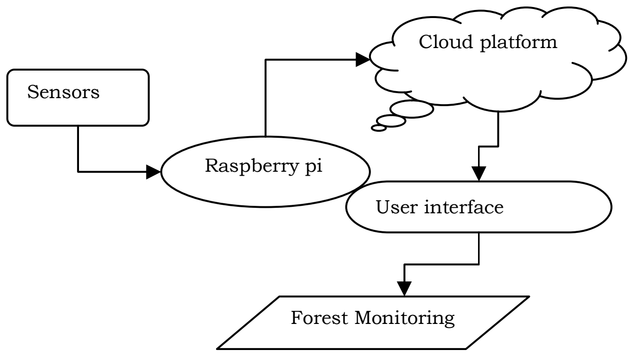

Fig. 2 Block diagram

C. Sensor details

The forest environment's humidity and temperature levels are monitored. Insight into the climatic variables that influence the forest environment is significantly enhanced by the information it provides on the surrounding temperature and relative humidity. Gas sensors measure the presence and concentration of different gases in the air. These sensors help monitor forests for a wide range of gases, including carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), and volatile organic compounds (VOCs). Keeping updated on gas levels is a helpful way to measure air quality, locate possible pollution levels, and observe changes in the environment of forests.

Smoke detectors can measure up to minute traces of smoke in the air. Their purpose is to detect the presence of smoke, an indicator of a fire, or possible fire dangers in wooded areas. A fire sensor is a component used to detect the presence of fire or other heat sources. A fire or fast temperature increase can be detected by several technologies, such as sensors for temperature, infrared sensors, or flame detectors. To respond quickly and effectively to fires, fire sensors play a critical role in detecting them at an early stage.

Together, the information gathered by these sensors is beneficial in assessing the safety of a forest and preventing fires. Information into the forest ecosystem's state, monitoring of environmental elements, and preventative forest conservation and management are all made feasible by combining data from various sensors.

D. Cloud computing

The cloud is crucial in the real-time sensor data fusion and visualization system for monitoring the forest environment. The acquired sensor data can be processed and stored using the cloud platform's scalable and adaptable features. Temperature, humidity, gas, smoke, and fire sensor data may all be seamlessly integrated with this system. The integrity and accessibility of stored data are guaranteed by the cloud's centralization and security features. It houses data fusion algorithms that compile information from various sensors to provide a complete picture of the forest's ecosystem. The computing capacity in the cloud allows for instantaneous analysis and insights.

The cloud is a for visualization applications such dynamic dashboards and graphical data representations. To help users remotely monitor and assess forest conditions, these visualizations show the integrated sensor data understandably.

The cloud-based technology allows off-site access, allowing forest managers, and supervisors to use real-time data to influence their decision-making. The cloud's dynamic capacity to assign computer resources in response to demand significantly contributes to its scalability. This ensures the system can handle plenty of sensor data simultaneously and survive busy times. The cloud's adaptability makes it easy to include third-party services and technologies, paving the way for future improvements and updates. It allows for remote access and access from any location and scalability in data storage, processing, visualization, and system extension.

III. RESULT AND DISCUSSION

The technology allows for continuous monitoring of forest conditions, including temperature, humidity, gas concentration, smoke, and fire. The results are improved awareness of the forest's condition as well as enhanced methods of risk assessment and management. The system is constantly analyzing the data from the integrated sensors in order to identify irregularities such as changes in temperature, abnormally high or low gas levels, and the presence of smoke and flames. Early detection facilitates quick reaction and prevention, reducing the potential of hazardous effects on the forest environment.

It provides analytics on sensor data and helps forest supervisors and users see that data so they may make data-driven decisions. Effective forest conservation and methods for resource management can be developed and implemented with its help due to its ability to examine environmental impacts, identify patterns, and carry them out. Real-time monitoring and alerts make it possible to respond rapidly to forest hazards such fires. Reduced damage from forest fires is achieved by better early warning systems, coordination with relevant authorities, and the use of effective firefighting approaches.

Maintaining forests is made easier because to the system's ability to provide accurate and detailed information on the forest's environment in real time. It aids in the identification of environmentally fragile areas, the evaluation of human activity's impact, and the implementation of sustainable measures to protect the planet's natural wealth and diversity. The system's cloud-based storage and preservation of sensor data also makes it easy for retrospective analysis. The forest ecosystem can be monitored and analyzed over extended periods to provide light on long-term patterns, the effects of climate change, and the success of conservation efforts, all of which are useful for future planning and policymaking.

Benefits of the system include better danger identification and response, more efficient forest conservation, and the potential to conduct long-term analyses for effective forest management. These results help in more efficient use of resources, conservation of environments in forests, and long-term environmental health. The Raspberry Pi receives and processes sensor data and connects with other devices for real-time monitoring, fusion, and display of data from the forest environment; a circuit diagram is shown in Figure 2.

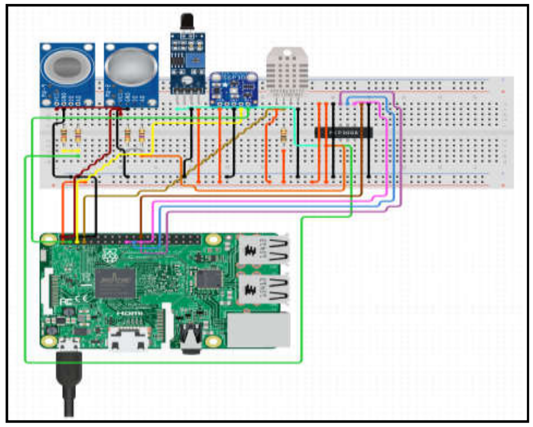

Fig. 2 Circuit diagram

The circuit diagram for the Raspberry Pi and sensor system shows how all the various parts are connected and work together. The Raspberry Pi is the brains of the operation, sitting at the heart of the circuit. The sensors, such as temperatures and hygrometers, gas detectors, smoke alerts, and fire alarm detectors, are all linked to the Raspberry Pi through analog or digital input ports. Jumper wires are used to ensure the electricity flows properly while making these connections. The Raspberry Pi and the sensors get their electricity from a power source, such as a USB cable or an external power adapter. The Raspberry Pi can send and receive data thanks to the several communication ports it has on board, including USB, Ethernet, and Wi-Fi.

Cloud computing provides an environment of security for a wide range of data. Humidity, temperature, gas, smoke, and fire sensors contribute to this category, as can integrate sensor data that integrates values from several sensors. Long-term patterns may be examined using historical sensor data, with extra context provided by metadata. Cloud computing may also be used to save analytical findings and visual data for use in future real-time or historical representations.

Data security and privacy protection are crucial for protecting private data. Information is saved in the cloud according to the needs of the system. The data from the sensors are shown in Table 1. The data can change depending on the types of sensors used, the state of the surrounding environment, and the accuracy with which the sensors were calibrated.

Table. 1 Sensor Values

Sensor	**Values**
Temperature	25.3 °C
Humidity	57.8 %
Smoke	1.35 ppm
Fire	detected

Table 2 shows the results of a gas sensor placed in a forest. The numbers provided are estimates that can be off based on factors such as the kind of gas sensor used, its accuracy, and the presence or absence of gas emissions in the forest.

Table. 2 Gas Sensor Values

Carbon Dioxide	425 ppm
Carbon Monoxide	12 ppm
Methane	0.03%
volatile organic compounds	0.012 ppm

The system has to be responsive to sensor data fast and have a low latency. Abnormalities may be found, and actions are taken quickly when data is processed and analyzed in real time. Data fusion algorithms' precision is crucial to provide reliable and comprehensive insights. Accurately representing the forested environment requires that the system incorporate data from several sensors. For optimal performance, the system must process vast amounts of sensor data at peak times and when several sensors are active. The capacity to accommodate a growing volume of data without slowing down the system is known as scalability.

Users should be able to have an accessible and engaging experience with the visualization component, especially when working with massive amounts of information. Users can further examine the visible data because of efficient display and manipulation. If the system is to monitor the forest environment constantly, it must be very reliable and available. It should be built to recover automatically to ensure data accuracy and system operation in the event of a breakdown. Privacy and security of the obtained sensor data are essential performance factors. Sensitive data should be protected from theft, loss, or misuse by the system's strict security protocols.

The system's efficiency is enhanced by its capacity to identify abnormalities quickly and precisely in real-time. It has to be sensitive enough to identify hazards in the forest and have a low false positive rate. User interactions with the visible data should be quick and easy. Therefore a dynamic interface is essential. Faster reaction times and more fluid interactions improve the user experience and aid in making wiser choices. Maintaining the system's performance over time requires constant attention, including testing and tuning. By constantly updating and improving the system, developers can eliminate any remaining performance issues and maximize them for maximum efficiency.

IV. CONCLUSIONS

In conclusion, the approach provides practical suggestions for monitoring forests' environments conditions. The system's collection of sensors allows for a 360-degree view of the forest's current state in near-real time. The collected sensor data is stored, processed, and shown on a cloud platform so that users can make forest conservation and management decisions. The system's capacity to keep checks on environmental conditions, including temperature and humidity, as well as gases, smoke, and fire, helps to detect problems early, allowing for quick action and prevention. The scalability provided by the cloud-based platform ensures that the system can process massive amounts of sensor data. With the ability to fuse and visualize data in real-time, users can better understand the forest ecosystem and make decisions based on data. The system's effectiveness depends on its speed, accuracy of data fusion, capacity to scale, dependability, and ease of use. The system must be continuously monitored and configured to the optimize parameters in order to maintain its efficiency and reliability over time. The system suggests proactive forest management and conservation actions while also promoting reliable data transmission to users and forest monitoring. The system offers a scalable and reliable means of real-time monitoring, analysis and display of the forest environment by capitalizing on the features of cloud technologies. The system's use in promoting long-term forest sustainability will grow as sensor technology and information processing methods continue to improve.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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