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IoT-Based Real-Time Monitoring and Testing of AI Applications for Analysis and Forecasting

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ABSTRACT

One of the most essential elements for the continuation of life on Earth is air. Air pollution is continuously rising due to industrial factors and the use of fossil fuels. Because these elements have an impact on health and prosperity of life on Earth, it is necessary to constantly examine the quality of the air in our surroundings. The implementation and strategy of IoT based air pollution tracking and projecting using AI techniques are presented in this study. Due to high levels of dangerous chemicals, air pollution in industrial settings, especially during the chrome coating process, puts workers' health at serious risk. The demand for effective testing and monitoring procedures to guarantee system reliability, safety, and efficiency has grown due to the quick development of automated production. A real-time tracking and assessment method for IoT-based autonomous systems is presented in this paper. The proposed system integrates IoT-enabled sensors, online information technology, and AI approaches to continuously collect, process, and evaluate real-time data from connected devices and automated settings. Since the system consistently detects possible issues long before they become serious mistakes, our results show a large rise in the early detection of abnormal trends. This study demonstrates how IoT and AI may be successfully integrated to enhance industrial management. It also emphasizes the concrete advantages of this integration process, such as the system's flexibility and ongoing learning, which guarantee its long-term efficacy.

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1. INTRODUCTION

Data-driven solutions to lessen this dilemma are provided by technological developments in IoT, AI [1], and smart water management systems. Their conclusions emphasize the necessity of conservation that is specific to the area. Based on this, SGWCS integrates AI-driven efficiency and game-based behavior modification in smart water supplies [2]. When taken as a whole, these strategies show that scalable, successful solutions need to combine cutting-edge technology with incentives tailored to the particular circumstances.

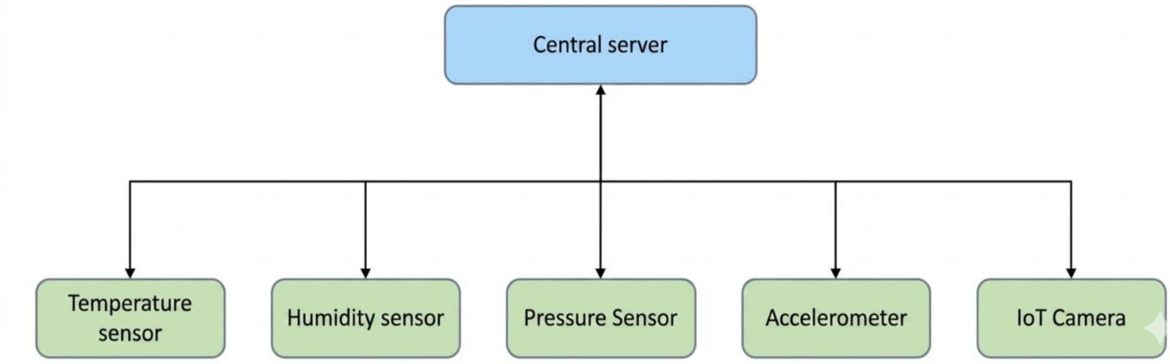

Figure 1. The Overall Design of the Implementation Ecosystem

The implementation environment's suggested architecture was created to maximize data collecting, delivery, and evaluation efficiency in an Internet of Things ecosystem. This framework, as shown in Figure 1 [3], is a straightforward but reliable depiction of how various IoT devices communicate with a single server. Depending on the type of connection used, each IoT device is connected to the centralized server via either an Ethernet connection or WiFi signals. To demonstrate the network's adaptability and scaling, it is essential to demonstrate that every device has a separate connection to the server.

2. LITERATURE REVIEW

The IoT technologies are used to retrieve data collected by equipment. Real-time comparisons between data from an amalgam simulation and the productivity and dependability of a practical system are made [4]. The simulation monitors output and input variables using continuous dynamics at the machine level and estimates performance indicators at the system level using discrete-event systems. In order to identify anomalous circumstances based on variations of actual outputs at various phases of the process, simulated outputs are utilized as an example. Robotics and CNC machines are used in a fully automated manufacturing process tested to apply this tracking technique. A programmable logic controller is used to integrate machines on an Ethernet/IP management network in order to communicate information and coordinate operations. The ability to track in real time and record performance defects within confidence levels was shown by the results.

Farmers must monitor and regulate the just distribution of water to all plants on the entire farm or in accordance with crop requirements due to the unequal natural dispersion of rainfall. To select the best approach, a thorough investigation of every environmental parameter is necessary. The development of wireless sensors and smaller sensor devices has made it feasible to employ them for Precision Agriculture (PA) applications [5], such as automated environmental tracking and greenhouse parameter management. Data transmission in the Field Bus idea is primarily managed by an appropriate wired communications system, which may now be substituted with a hybrid system to take use of both and automated system efficiency and capacity.

Patients, especially those in the critical care unit (ICU), can receive health services from this device. The most important treatment that many patients obtain from hospitals is the saline medical treatment, heart rate monitoring, and temperature monitoring [6]. This paper describes the implementation of an IoT based system that will track the amount of IV fluid levels and monitor heartbeat and heat based on the output provided by a hardware device that consists of a NodeMCU, pulse meter, and thermometer. Additionally, if the IV fluid level falls below the acceptable level specified in the developed computational rule, an improved alert system is triggered.

[7] Suggests an advanced Internet of Things system that uses hybrid Long Short-Term Memory (LSTM)–Gated Recurrent Unit (GRU) architecture for projections, secure communication, and real-time data gathering. By addressing the short-term dependency issues of GRU and the computational limitations of LSTM, the hybrid design improves time-series prediction precision and efficacy. The model gets a minimum $R2$ score of 82.04%, a Root Mean Square Error (RMSE) of 8.15%, and a Maximum Mean Absolute Error (MAE) of 3.78% for all prediction use cases, demonstrating the dominance of the suggested model for practical use circumstances. Additionally, a comparison investigation demonstrates that the suggested model performs better than independent LSTM and GRU designs, improving the IoT's dependability in real-time energy and environmental prediction.

It offers a number of integration options for gathering, displaying, and analyzing data from sensors on one platform. AI has gained a lot of popularity recently and is utilized in many different applications, such as the Internet of Things. After recognizing the present state of suitable AI technologies in IoT apps, SEMAR must integrate AI to improve its capabilities in order to help this increase. In this work [8], a thorough analysis of IoT applications in the literature that use AI approaches. Predictive analysis, picture classification, object identification, text recognition, hearing, NLP, and cooperative AI are all covered. The important criteria, including software specifications, input/output (I/O) data formats, processing approaches, and calculations, are then taken into account to determine the features of each methodology. Third, [9] use the results to design how AI approaches are integrated into SEMAR. Lastly, we go into SEMAR use scenarios for AI-based IoT applications. Future projects will use the proposed design in SEMAR and apply it to Internet of Things application.

A real-time air pollution tracking and predicting system created especially for the chrome plating standard sector is presented in this research [10]. The system delivers real-time information on pollution concentrations and detects a variety of air contaminants, such as NH3, CO, NO2, CH4, CO2, SO2, O3, PM2.5, and PM10, with the help of IoT devices and AI techniques. To forecast pollution levels, LSTM, Random Forest, and Linear Regression methods are applied to the information gathered by sensors. For temperature and humidity forecasting, the LSTM model had a mean absolute percentage error (MAE) of 0.33 and a coefficient of variation (R^2) of 99%. With an R2 of 84% and an MAE of 10.11 for PM2.5, the Random Forest framework performed better than other models.

3. METHODS AND MATERIALS

According to the recommendation [11], for the model to be successfully implemented on an IoT device, it must generate precise outcomes and function effectively in a variety of real-time settings. The IoT gadget with the built-in model is evaluated in a lab or other comparable setting where all variables and circumstances can be tracked and controlled for the controlled setting testing scenario [12]. This enables you to assess the system's performance in optimal circumstances and identify underlying issues or apparent malfunctions. For instance, it is feasible to replicate a range of particular temperature and moisture levels and see if the gadget responds as anticipated.

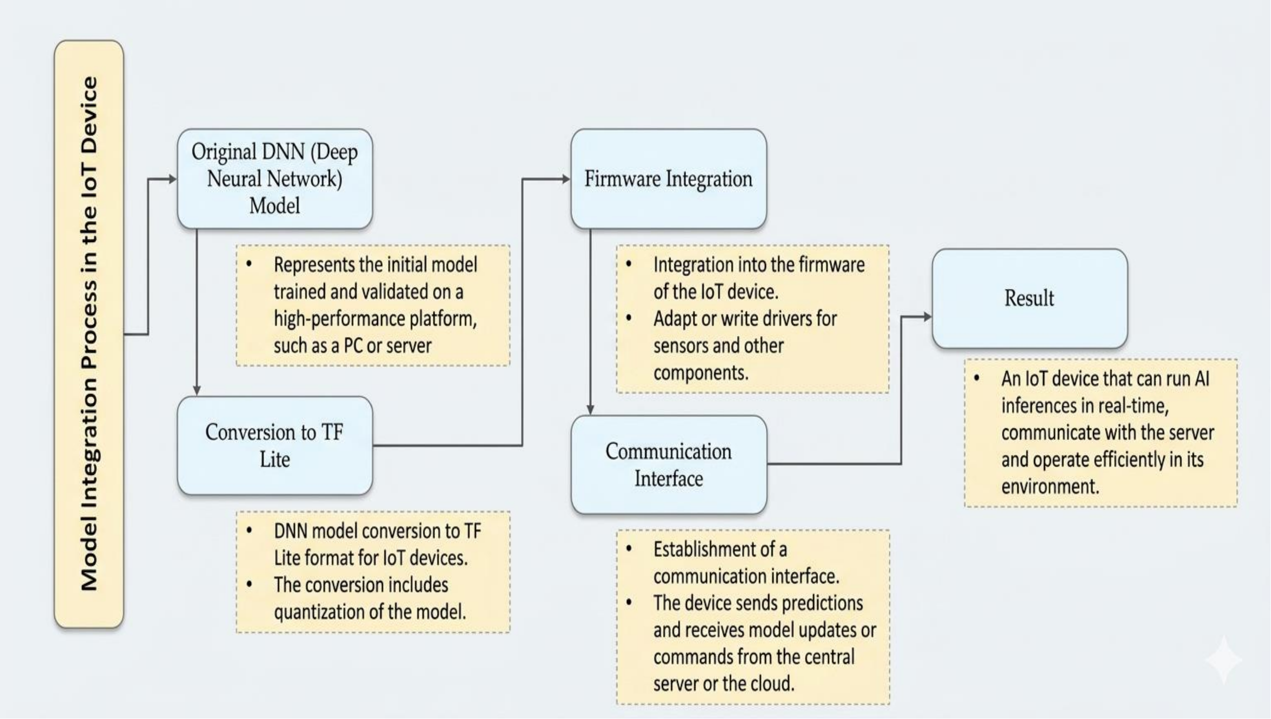

Figure 2. Proposed Model Integration Frameworks for Internet of Things Devices

The device is evaluated in the following real-simulated setting, which mimics the real-world conditions under which it is anticipated to function while yet allowing for the monitoring and the Proposed Model Integration Frameworks for Internet of Things Devices in Figure 2 [13]. This helps find issues that could not be seen in a controlled setting and offers a more realistic picture of system efficiency. One possibility would be to temporarily install the gadget in an establishment or smart home.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

The current study creates an AI-based adaptable system for IoT devices that monitor manufacturing machinery and the surrounding environment in light of technology advancements and the growing industry integration of standard AI systems. In order to maximize bandwidth and ensure quick reactions to anomalous events, the primary goal was to create a system that could effectively distinguish between vital data that needed to be sent right away and those that might be saved or processed local [14]. This approach is based on the basic notion that integrating AI into IoT devices at the data collection point can reduce network overhead and improve accuracy and speed of identifying major occurrences or trends.

4.1 System Operation in a Controlled Environment

The structure was first validated using a set of data created in a controlled environment inside the actual plant. In an ideal scenario, these statistics offered a strong foundation for assessing the system's efficacy and reliability [15]. Table 1 shows the results from the exterior temperature sensors over a ten-hour period.

Table 1. Temperature Sensor Results

Time (hr)	Temperature (°C)	Generated Alerts
1	24.5	No
2	25.3	No
3	26.7	No
4	35.2	Yes
5	34.8	Yes
6	23.9	No
7	24.1	No
8	33.5	Yes
9	33.9	Yes
10	24	

The humidity sensor's data over a 10-hour period are shown in Table 2. The findings demonstrate the system's ability to detect and document minute changes in the moisture content of the controlled environment [16]. The humidity ranges from 44% to 70%.

Table 2. Findings from a Standard Humidity Sensor

Time (hr)	Humidity (%)	Generated Alerts
1	50	No
2	52	No
3	49	No
4	44	No
5	70	Yes
6	67	Yes
7	47	No
8	68	Yes
9	46	No
10	49	No

The pressure sensor measurements gathered during a ten-hour period are displayed in Table 3 [17]. These data show that the system can identify and document changes in the regulated ambient temperature.

Table 3. Results of the Pressure Sensor

Time (hr)	Pressure (Pa)	Generated Alerts
1	101325	No
2	101250	No
3	101275	No
4	101220	No
5	101210	No
6	100900	Yes
7	100890	Yes
8	101260	No
9	100875	Yes
10	101310	No

The accelerometer readings during a ten-hour period are displayed in Table 4. The sound waves present in the controlled environment are represented by this data [18], which is expressed in meters per second squared (m/s2). Vibrating is an essential indicator of the condition and operation of industrial equipment.

Table 4. Accelerometer Sensor Readings

Time (hr)	Vibration (m/s^2)	Generated Alerts
1	0.002	No
2	0.008	Yes
3	0.004	No
4	0.003	No
5	0.007	Yes
6	0.005	No
7	0.003	No
8	0.004	No
9	0.006	Yes
10	0.007	No

A composite set of graphs showing important parameters tracked during ten hours in a controlled environment is displayed in Figure 3. The temperature in the first subsection stayed within a small range, but there were three prominent peaks when the predetermined level was exceeded during hours 2, 5, and 10. With a few small variations, the humidity sub-graph displays a mostly steady pattern. Additionally, there were variations in the stress in the third subsection, especially at hours 3, 6, and 9. Three places of interest are shown by the accelerometer's vibration in the 4th sub-graph during hours 2, 5, and 9, when the readings surpassed a particular threshold. Lastly, the fifth sub-graph shows the number of IoT sensor failures per hour, peaking at hours 2, 5, and 8.

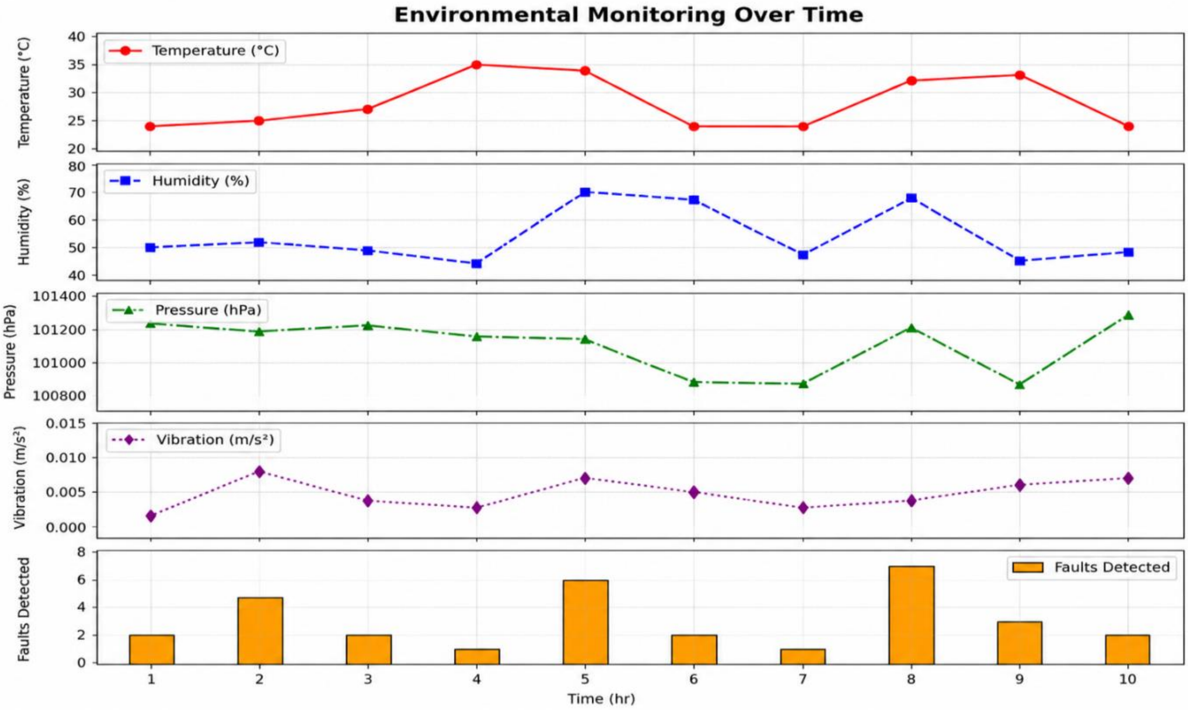

Figure 3. Environmental Monitoring Over Time

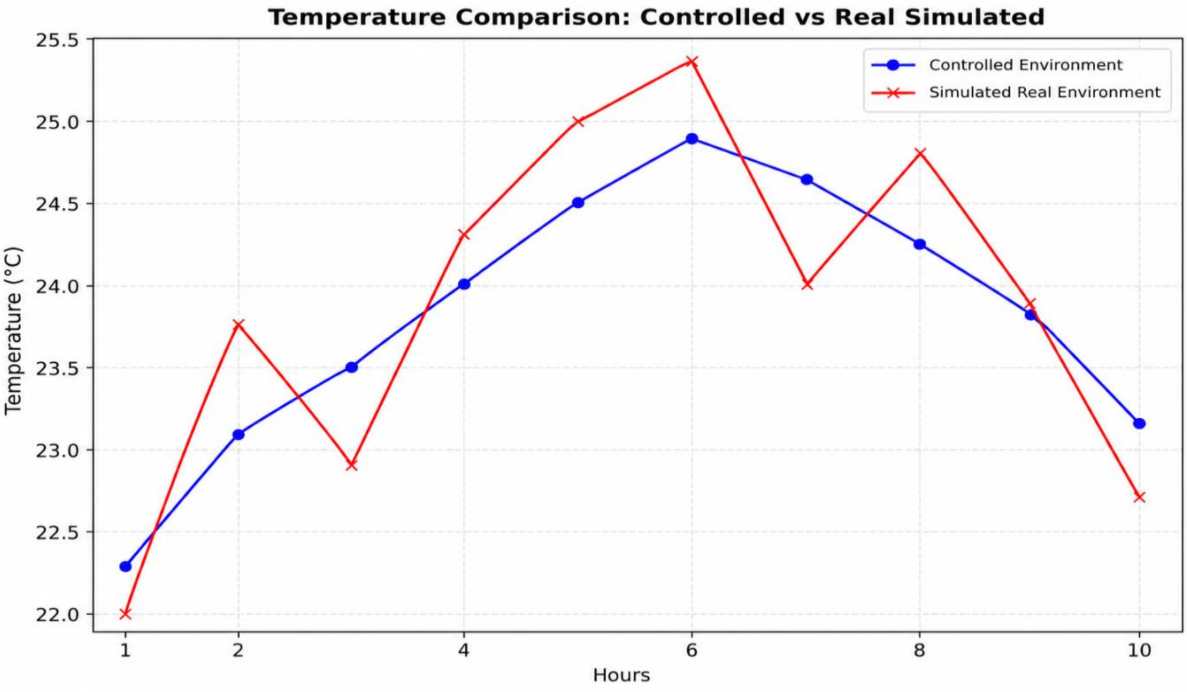

Figure 4. Temperature Comparisons: Controlled Vs Real Simulated

To comprehend the distinctions between achievement in controlled conditions and the actual simulated one, a visual comparison of the outcomes is crucial. A clear and contrasting perspective of the system's monitoring and recording of humidity and temperature in two distinct scenarios—a controlled setting and a modeled natural environment—is given in Figure 4. We are able to recognize some patterns and important traits at first glance.

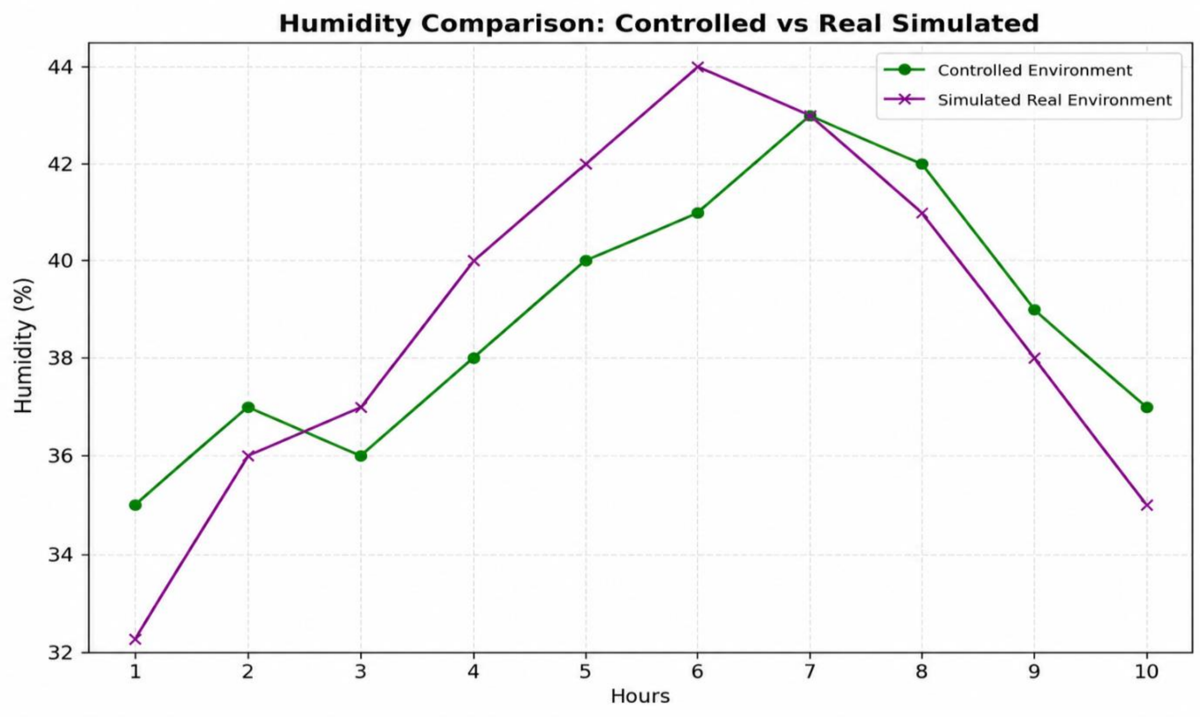

Figure 5. Comparison of the Findings from Pressure Sensors

Figure 5 compares the relevant pressure sensor data in the controlled and duplicated real settings. The sensor functions somewhat differently in these two situations. Readings are typically more consistent in the regulated conditions, indicating a setting free from notable disruptions.

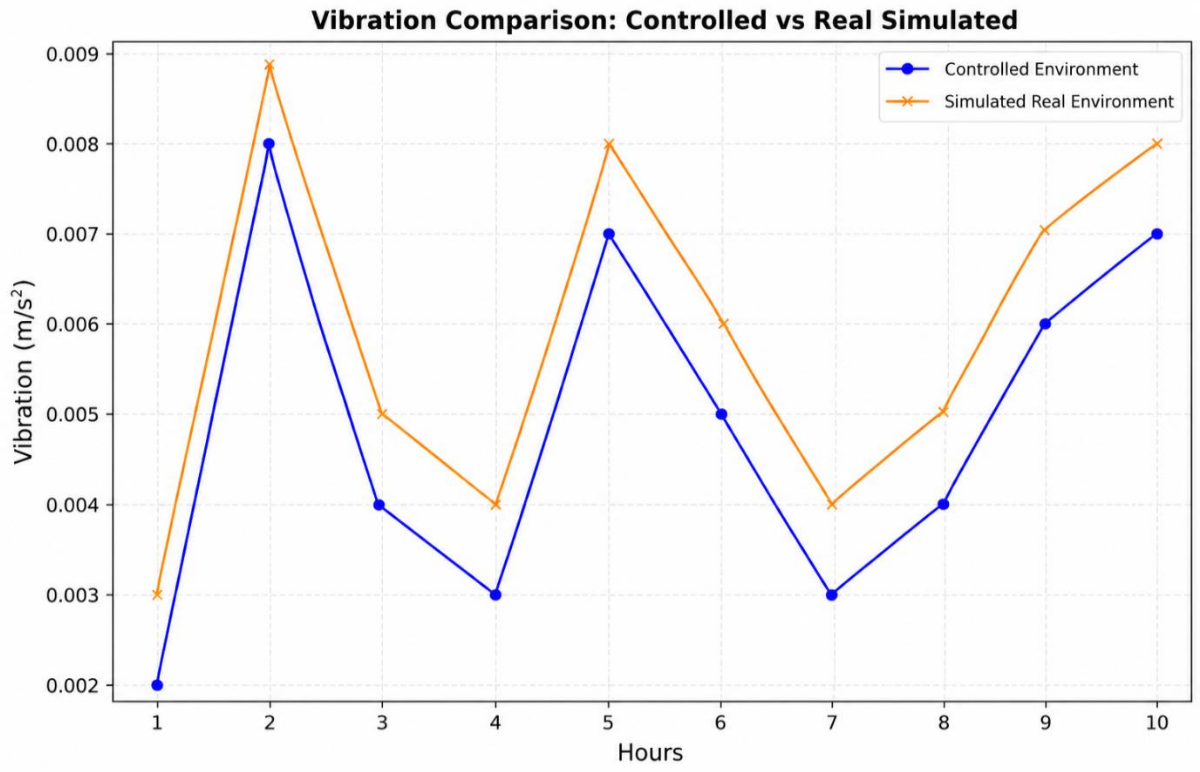

Figure 6. Comparisons of Vibrations

In above Figure 6 [19, 20], which contrasts the results from the regulated and replicated wild settings, displays the defect detection rate of the IoT camera. Examining the trends makes it evident that the camera regularly demonstrates the ability to identify issues in a controlled environment.

5. CONCLUSION

As the global economy enters a phase of increased interconnectedness and digitization, sophisticated monitoring technologies are crucial. Our solution has shown to be a reliable and efficient answer to this need since it deftly blends the capabilities of IoT devices with cutting-edge AI techniques. From a straightforward instrument for gathering data, this system has developed into a complete solution that encourages proactive and anticipatory oversight of industrial processes. The system has had major immediate effects on everyday operations. Decisions are no longer only made in reaction to issues after they have emerged due to early warnings about possible failures or abnormal inclinations.

We have plenty of room to refine and expand our concept. Adding increasingly complex algorithms can improve the system's dependability and effectiveness as AI technology develops. Additionally, given the expanding Industry 4.0 trend, the solution's capabilities can be enhanced by combining additional IoT devices with computerized procedures.

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