Artifact Sentinel: A Real-Time IoT System for Artifact Safety and Conservation

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Abstract

As everyone knows, museums are houses for priceless artifacts that need to be preserved at all costs. It is important to note that these artifacts need to be stored in a suitable environment for preservation. The proposed "Deformation Evidence Guard" is an Internet of Things device that provides protection for deformation evidence and ensures that its environmental norms are maintained. Various sensors in this device work together to ensure that desired results are obtained. An alarm beeps, and an immediate alert is issued when movement is detected near an artifact, and an ESP takes a picture of a 32-came intruder. Technology also enables the sensor to continuously monitor temperature and humidity levels, presenting results on an LED display to help preserve as many artifacts as possible. This simple, automated device increases museum protection by reducing the possibility of theft and deterioration through real-time monitoring and environmental tracking.

The proposed model using high energy efficiency, the ability to monitor surroundings, motion sensing, and an attached camera, as well as features such as real-time reactions, consistent monitoring, and detailed tracking, making it a novel approach compared to existing.

Keywords: Artifact protection, IoT security system, Motion detection, Environmental monitoring, ESP32-CAM, Real-time alert, Buzzer alarm, Intrusion detection, Smart surveillance, Temperature and humidity tracking, Automated monitoring.

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1. Introduction

Museums are cultural places where the origins of cultures and significant historical events are exhibited. It is crucial to ensure that artifacts stored in the museum are well maintained so they can recount the stories of the passage of time. This involves constant monitoring and ensuring that the artifacts are in a suitable environment. Conventional security systems often lack real-time monitoring and automated threat identification, exposing artifacts to theft and environmental damage. A creative solution to this issue is 'Artifact Sentinel,' an IoT-based preservation and security system developed to address the challenges that may arise with artifacts in museums. The intent of the Artifact Sentinel device is to keep the artifacts under observation at all times and ensure they are in a suitable environment. It is equipped with motion sensors, an ESP32-CAM, and a buzzer alarm to detect unauthorized movement around artifacts and alert the necessary staff by triggering an alarm and capturing their snapshot. The system also monitors environmental conditions continuously and notifies personnel when conditions are not favorable (William et al., 2023) [1]. The innovation of the new system 'Artifact Sentinel' lies in its potential to combine both security and environmental monitoring into one affordable and compact IoT-based system, whereas current systems are typically designed to address only one issue, either security or environmental monitoring.

2. Literature Survey

Artifact preservation and automated museum security have been long-standing concerns, previously addressed by human observation and air-conditioned spaces. Later advances in IoT and automation have made it possible to address real-time observation and automated attack detection more effectively. Motion-detection security systems, environmental monitoring systems, and AI-based surveillance have been considered in earlier work and shown to perform effectively in offering enhanced security. Recent technologies and methods are discussed in this survey, along with vulnerabilities that Artifact Sentinel will resolve with integrated motion detection, real-time alerts, and environmental monitoring.

This article discusses how an IoT system, which monitors temperature and humidity in real-time with the help of data centers, is implemented. The system is seen to provide readings of environmental changes more accurately in various IT locations, and alerts are sent to the IT teams in an attempt to provide early intervention when less-than-optimum conditions are detected [1]. This work uses a camera and a PIR sensor module to construct a deep learning-based smart pest detection and repellant system. It improves pest control in smart agriculture by using an algorithm known as "Mask-RCNN" to accurately classify bugs and an ultrasonic buzzer to deter larger pests [3]. This study proposes an Internet of Things (IoT)-based system to monitor temperature and humidity in industrial settings using a NodeMCU and DHT11. Real-time data is shown using Arduino IoT cloud and mobile apps, and IFTTT is utilized to send safety and spoiling prevention notifications [5]. An IoT-based mushroom growing system was developed, providing remote monitoring and regulation of temperature, humidity, light, and soil moisture. A mobile/web interface is utilized to provide real-time image and video streaming and automated environmental control [7]. This paper proposed an intelligent intruder alarm and home automation system using ESP32-CAM, a vibrometer, and ATMega328P. It offers 95% average accuracy in security detection with the help of real-time monitoring, motion-activated alerts, and lighting control [9].

The study proposed an ATmega328P and NodeMCU-based IoT preventive system for power theft. Real-time electrical usage is monitored, and any irregularity detected by the cloud initiates safety features such as notifying the utilities and de-energizing the circuit to prevent any loss [11]. This study developed an ESP32-CAM and Telegram-based low-cost home security system. The system creates a live feed and alerts users on their telegram accounts upon detection of motion [12]. The project established a gas leakage detection and prevention system using Arduino Uno. Rising gas levels trigger the system to send SMS alerts to users and sound alarms, along with safety measures such as the closing of gas valves to offer protection to homes [16]. This research built a temperature and humidity monitoring system using Arduino and a DHT11 sensor, transmitting real-time data to a smartphone via Wi-Fi. Users can stay informed about the indoor air quality in the lecture hall [18].

Table 1. Summary of Existing Work

Ref. no.	Methodology	Motion Sensing	Camera	Temperature Monitoring	Humidity Monitoring	Alert
[1]	IoT cloud-based framework has been used for developing a real-time monitoring system by integrating modules such as DHT11, GSM/GPRS,and Atmega2560 microcontroller that transmits environmental data to PaaS platforms such	No	No	Yes	Yes	Yes

	as AT&T M2X for storage and monitoring.					
[3]	A pest detection and repellent system was developed by using deep learning that utilises a PIR and camera. Classification of pests is done with the help of Mask-RCNN algorithm and an ultrasonic buzzer is used to repel them in agricultural environments.	Yes	Yes	No	No	No
[5]	This involves using a NodeMCU ESP8266, DHT11 sensor, and Arduino IoT Cloud with IFTTT integration to enable real-time temperature and humidity monitoring, alerts, and remote access via a mobile app.	No	Yes	Yes	Yes	Yes
[7]	An IoT system that uses NodeMCU and Raspberry Pi to monitor temperature, humidity, light, and soil moisture in a mushroom chamber and control these factors based on real-time data from sensors, a NoIR camera. Blynk is used for cloud integration and data can be accessed through remote dashboards.	No	Yes	Yes	Yes	No
[9]	An ESP32-CAM, ATMega328P, and a vibrometer is used to detect if any intrusion occurs by sensing vibrations. The camera records the video in real-time and the system is controlled via an android app.	Yes	Yes	No	No	Yes
[11]	The electricity theft detection system is powered by ATmega 328p and NodeMCU to monitor electricity usage and transmit	No	No	No	No	Yes

	live status via cloud, and provide real-time alerts and disconnection of circuits when unusual activity is detected					
[12]	A laser beam and LDR based setup is implemented to detect any intrusions by monitoring light intensity changes. If the beam is obstructed, the resistance of the LDR changes, which triggers the ESP32-CAM to capture and send an image with the help of a telegram bot in real-time.	Yes	Yes	No	No	Yes
[16]	An arduino Uno paired with an MQ gas sensor is used to detect if there are any leaks. When a predefined level is found to be exceeded, alert is sent in the form of SMS and a buzzer is turned on. The gas valve is shut by servo motor to ensure safety.	No	No	No	No	Yes
[18]	Arduino is paired with a DHT11 sensor to measure real-time humidity and temperature. The data values are transmitted with the help of WiFi to a smartphone application, which displays data in real-time.	No	No	Yes	Yes	No

The existing works have been found to implement motion detection or environment monitoring independently; there is a lack of systems that combine both functionalities in a compact form with low power consumption. Some existing systems also lack alert mechanisms or real-time video or photo capture for use by authorities, which this work aims to address.

3. Proposed Work

Artifact Sentinel is an Internet of Things real-time system for artifact conservation and security through the provision of real-time monitoring of unauthorized movement and environmental factors. It is developed with key features in mind, such as compactness, precision, and affordability. 'Artifact Sentinel' employs a PIR motion sensor to identify any unwanted movement in the area close to the artifact, alerting the authorities immediately. This feature makes 'Artifact Sentinel' an early warning device that helps prevent the potential destruction of museum artifacts. The device is highly beneficial for artifacts stored in parts of the museum that are not always under constant human surveillance. Upon detecting movement, the ESP-32 CAM is activated to capture an image of the source of movement, which is immediately transmitted to the authorities for review and documentation. The device's ability to react to real-time unwanted movements enables authorities to take immediate action against the source to protect the artifact. Additionally, the device reduces dependency on human surveillance. Another feature integrated with Artifact Sentinel is its capability to monitor environmental conditions. Most artifacts, such as paintings, manuscripts, textiles, and photographs, need to be preserved within specific temperature and humidity levels to prevent damage. The environmental monitoring sensor DHT11 continuously monitors the temperature and humidity, comparing them with ideal values. When the values reach undesirable levels, a warning is sent to the concerned authorities, prompting immediate action for the conservation of the artifact. Artifact Sentinel warnings are sent as notifications via Blynk IoT, which collects data from the ESP-32 CAM module. This system helps send real-time warnings to the relevant personnel so that prompt action can be taken. The temperature and humidity readings measured continuously by the DHT11 sensor are designed to be displayed on an LED screen for easy readability. The device is designed to consume low power by utilizing power-saving components compared to other devices in the market. It also provides fast response and smooth communication when necessary, facilitated by the efficient operation of the components utilized in the device. The Artifact Sentinel architecture is shown in Fig 1.

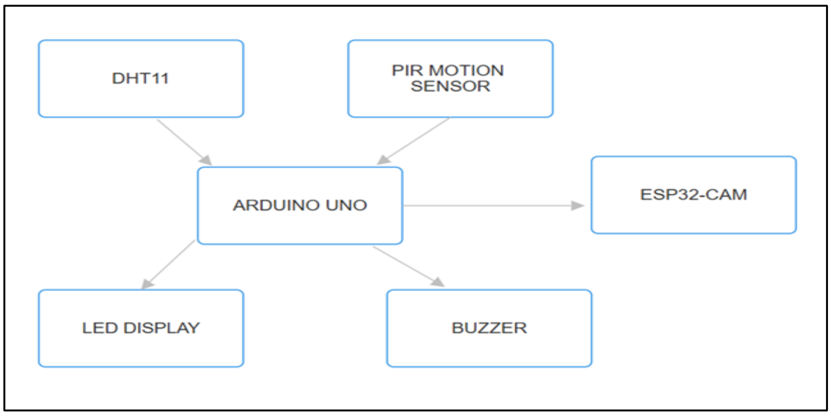

Figure 1. Artifact Sentinel Architecture

Artifact Sentinel's circuit is made of components that are accurate, reliable, and power-efficient. The PIR sensor, DHT11, ESP32-CAM, LCD display, and buzzer are interfaced with an Arduino Uno. The interconnection of the components in the circuit is indicated by Fig. 1.b. The components used in the system are chosen based on parameters such as precision, power efficiency, cost, and size. For example, we have used the DHT11 instead of other options available to us, such as the DHT22, due to its accuracy and low power requirement for indoor use over the DHT22. Likewise, we have selected the motion detection sensor to be a PIR sensor due to its human-specific motion detection, resulting in fewer false alarms compared to other options available to us, such as microwave sensors. The data sensed by the sensors are sent to the Arduino Uno at regular intervals using its built-in digital and analog read functions. The data received from the sensors are processed locally and compared with predefined values (threshold values) pre-loaded in the microcontroller memory. Based on the results, required actions are taken, such as triggering the buzzer, camera, and sending warnings to the authorities. The system does not possess long-term local storage but is designed to emphasize monitoring and communication. The system diagram is represented by Fig. 2, and the 'Artifact Sentinel' device is represented by Fig. 3.

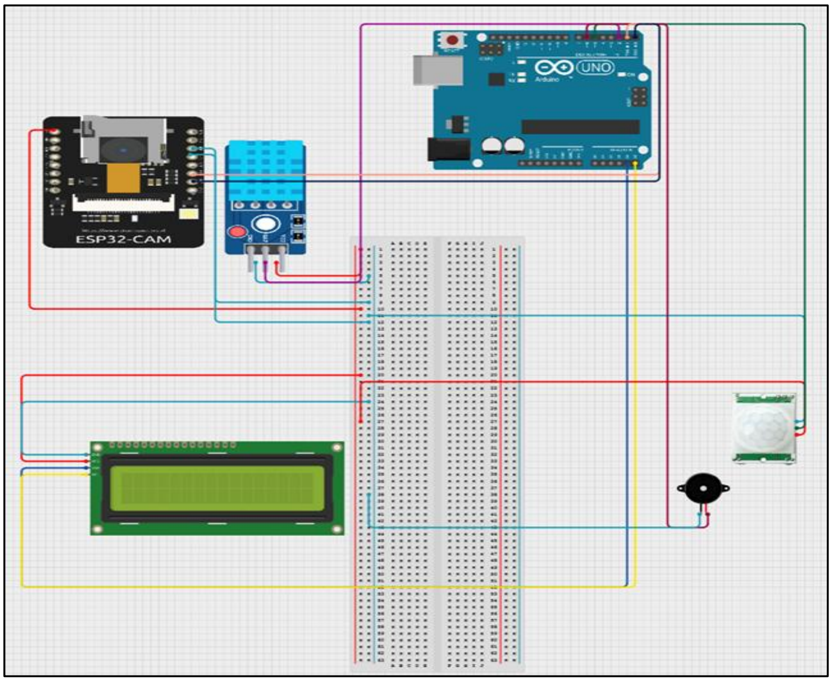

Figure 2. Circuit Design of the Proposed Model

Artifact Sentinel is designed with museum use in mind, where artifacts must be stored in controlled environmental conditions and under rigorous security. Compared to office and household monitoring, microclimate variations are also logged without interfering with visitor traffic or invading their privacy. If utilized in agriculture and household applications, parameters such as environmental boundaries, storage regulations for data, and alert mechanisms must be modified according to the evolving needs.

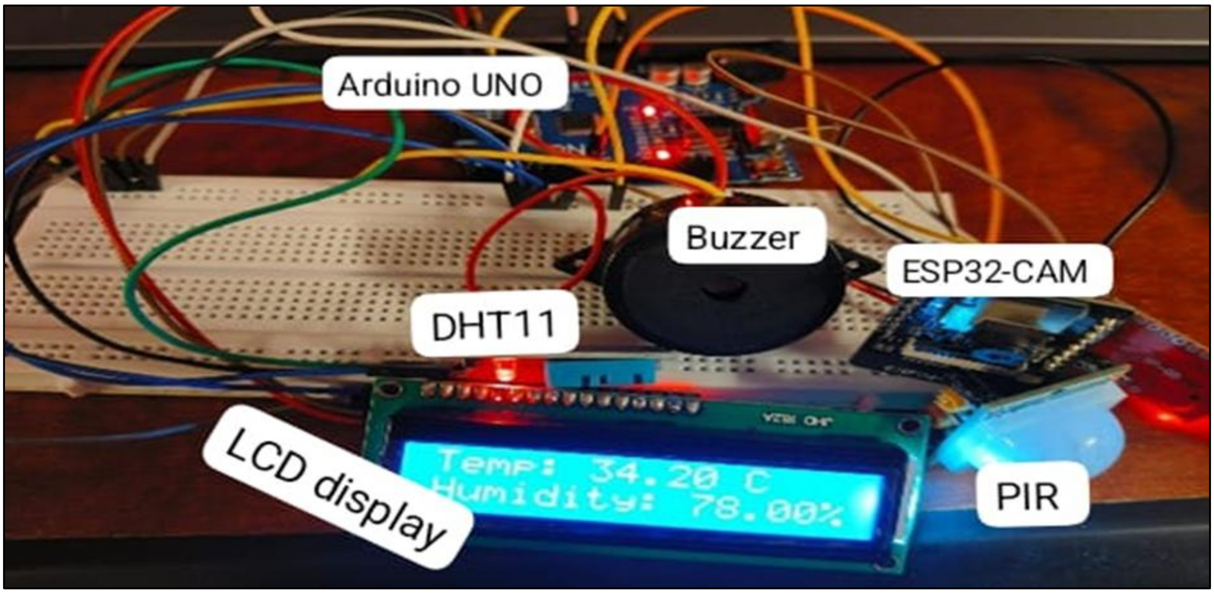

Figure 3. Hardware Setup of the Proposed Model

The components implemented in the device 'Artifact Sentinel' were chosen after thorough testing with available alternatives and a comparison based on pros and cons. The PIR motion sensor was selected after comparison with sensors such as HB100, BCWL-0516, and WaveShare.

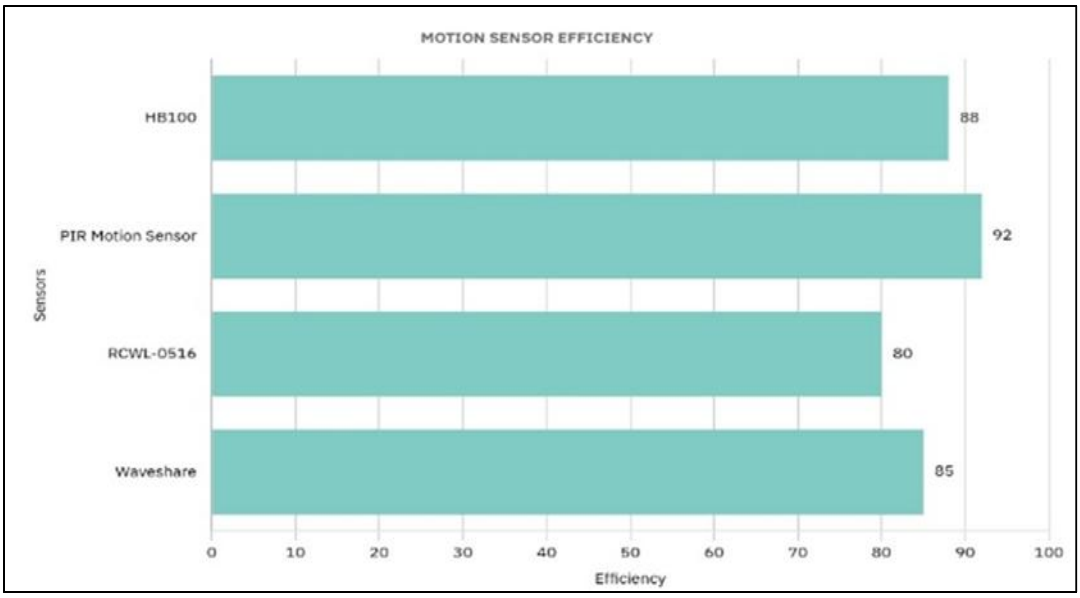

Figure 4. Motion Sensor Efficiency

The PIR sensor was deemed the most appropriate sensor for Artifact Sentinel as it is accurate, inexpensive, has low power consumption, and compact size. The comparison of the motion sensors is depicted in Fig 4. We have taken into account the handling of the device during power outages. The low power consumption modules help the system run on backup power.

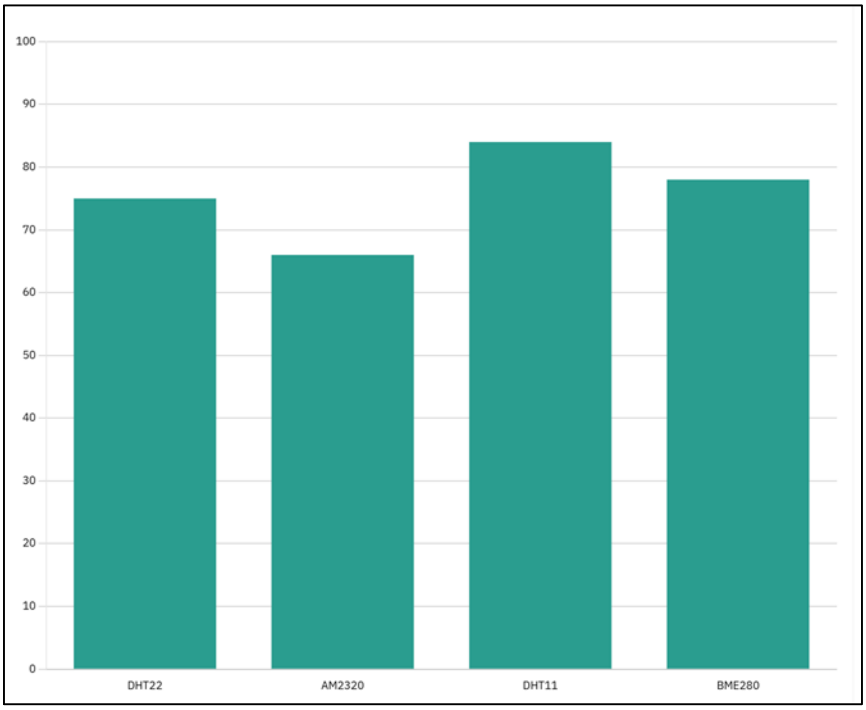

Figure 5. Temperature and Humidity Sensor Efficiency

The DHT11 sensor was finalised after comparing it with available alternatives such as the DHT22 and AM2320. The DHT11 was ideal in every way to be incorporated into Artifact Sentinel, as it had low power consumption, high accuracy, suitability for indoors, and a low cost. The comparison of the temperature and humidity sensors is shown in fig 5.

3.1 Components

Arduino UNO:

The Arduino Uno is a popular microcontroller board based on the ATmega328P, widely used for prototyping IoT and embedded systems. It features digital and analog I/O pins, a USB interface, and runs at 16 MHz. Known for its simplicity, low cost, and open-source design, it's ideal for beginners and hobbyists. The Arduino Uno supports easy programming via the Arduino IDE and has strong community support. (Fig 6) [24].

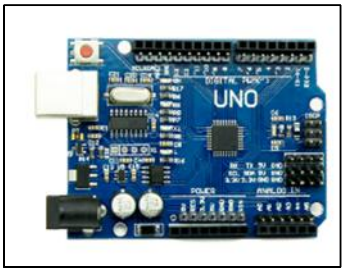

Figure 6. Arduino UNO

Buzzer:

A buzzer is an electronic component that produces an audible sound when powered, often used in alarms and alert systems. It operates using piezoelectric or electromagnetic principles. Buzzers are commonly found in security devices, timers, and notification systems. Their simplicity and effectiveness make them ideal for quick audio alerts. (Fig 7).

Figure 7. Buzzer

PIR Motion Sensor:

A Passive Infrared (PIR) sensor detects motion by sensing changes in infrared radiation emitted by objects. It is widely used in intrusion detection and motion-activated systems. PIR sensors are energy-efficient and cost-effective for monitoring human presence. They are commonly used in security alarms, automatic lighting, and smart home systems. (Fig 8).

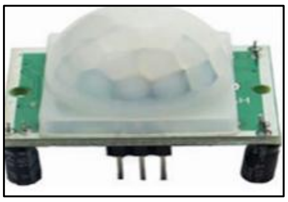

Figure 8. PIR Motion Sensor

DHT11 Temperature and Humidity Sensor:

A digital temperature and humidity sensor provides real-time readings crucial for environmental monitoring. It ensures stable conditions in sensitive spaces like museums and archives. These sensors help protect artifacts from damage due to climate fluctuations. They are compact, reliable, and easy to integrate into monitoring systems. (Fig 9).

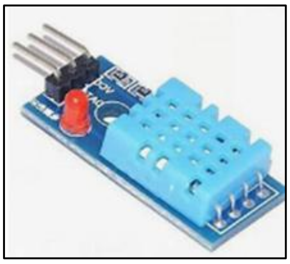

Figure 9. DHT11

ESP32-CAM:

The ESP32-CAM is a low-cost microcontroller with an integrated camera module and built-in Wi-Fi capability. It is widely used for surveillance and remote monitoring by capturing images or video and transmitting data wirelessly. Its compact size and low power consumption make it ideal for IoT-based camera applications. The ESP32-CAM supports real-time streaming and motion-triggered image capture (Fig: 10).

Figure 10. ESP32-CAM

LCD Display:

An LCD display is a screen used to visually present information like temperature, humidity, and system status in real time. It enables users to monitor environmental conditions or system performance at a glance. Commonly used in embedded and IoT projects, LCDs are compact, energy-efficient, and easy to interface with microcontrollers. (Fig 11).

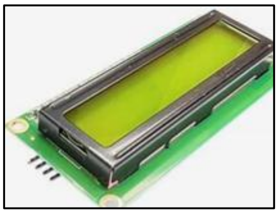

Figure 11. LCD Display

3.2 Operation Flow

The Artifact Sentinel operates by continuously monitoring the environment for any unauthorized movement, along with the environmental factors surrounding the artifact to be guarded. If any unauthorized movement occurs, the PIR motion sensor detects it instantly. The PIR motion sensor activates the ESP32-CAM contained in the device to take a snapshot of the surroundings, potentially capturing a photo of the source of the disturbance. The snapshot is transmitted along with a message to the respective authorities. A buzzer is also activated the moment any motion is detected by the PIR sensor, urging immediate action. The sequence of activities that occur is illustrated in Fig. 12.

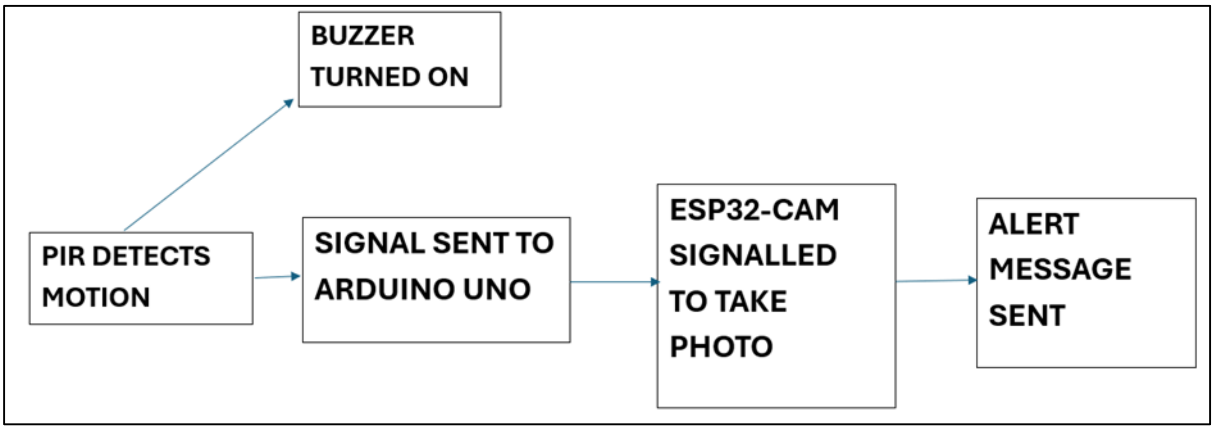

Figure 12. Flow of Motion Detection

The DHT11 performs a critical duty of continuously sensing the environment for humidity and temperature. These values are compared in real time with a hardcoded comparison mechanism that comprises ideal values, which can be altered as desired. If the sensed values deviate significantly from the ideal values, an alert message is sent to the authorities to ensure that immediate action is initiated. The temperature and humidity values sensed by the DHT11 are also sent to an LED display, which aids in observation activities. The sequence of activities that occur is indicated in Fig. 13 & Fig. 14 depicts a working scenario.

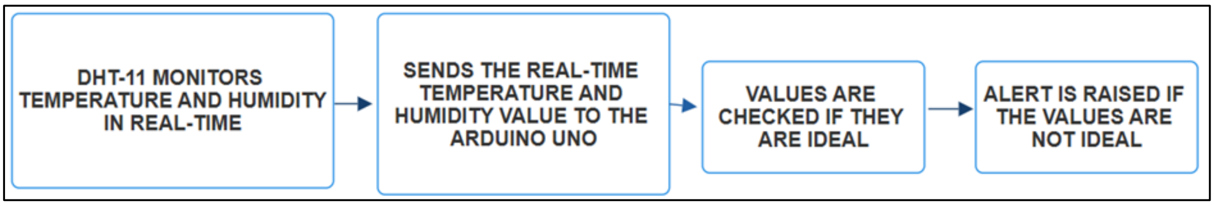

Figure 13. Flow of Temperature and Humidity Monitoring

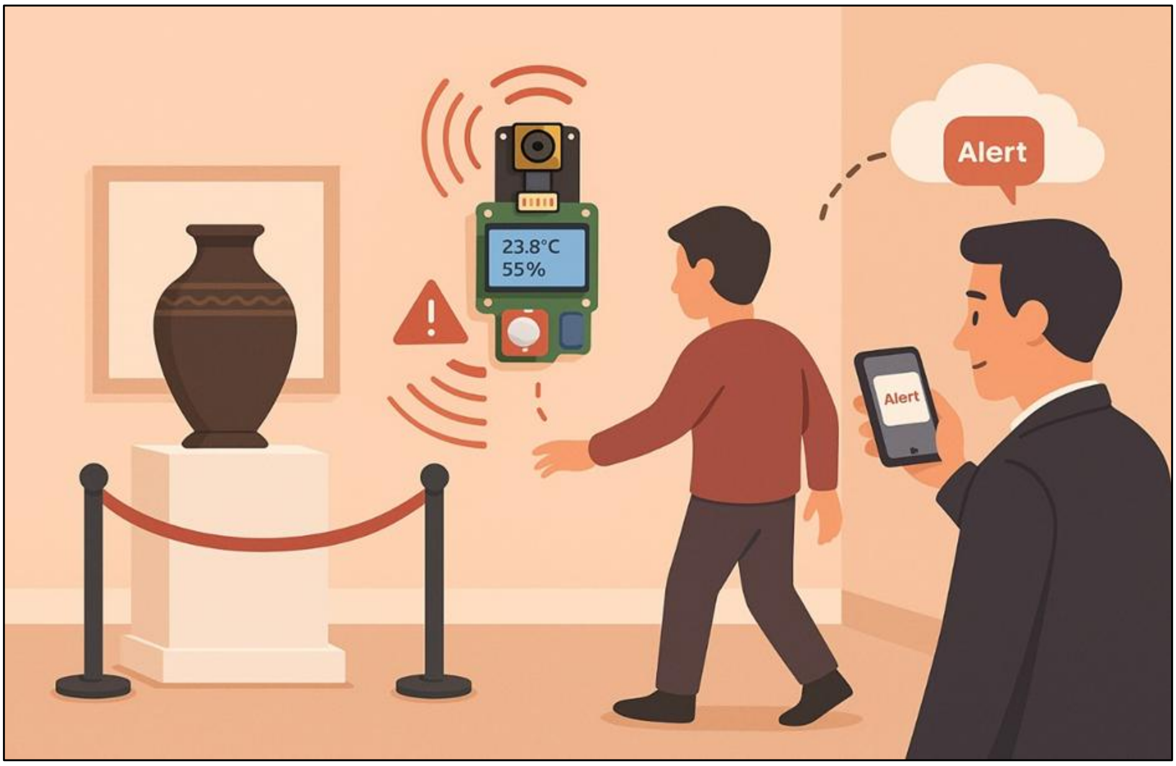

Figure 14. Working Scenario

4. Results and Discussion

Table 2. Performance Evaluation

Feature	Accuracy	Evaluation Method
PIR Motion Detection	92%	Detected 46 out of 50 intrusions
Environmental Sensor (DHT11)	±1°C / ±5% RH	Compared with standard thermometer & hygrometer
Alert Notification (via ESP32-CAM)	100% delivery	All 10 intrusion events triggered the camera and sent a message
Intruder Image Capture	92% success	23 out of 25 images were clearly identifiable
Response Time	~2.5 seconds	Time from motion to alert on recipient device

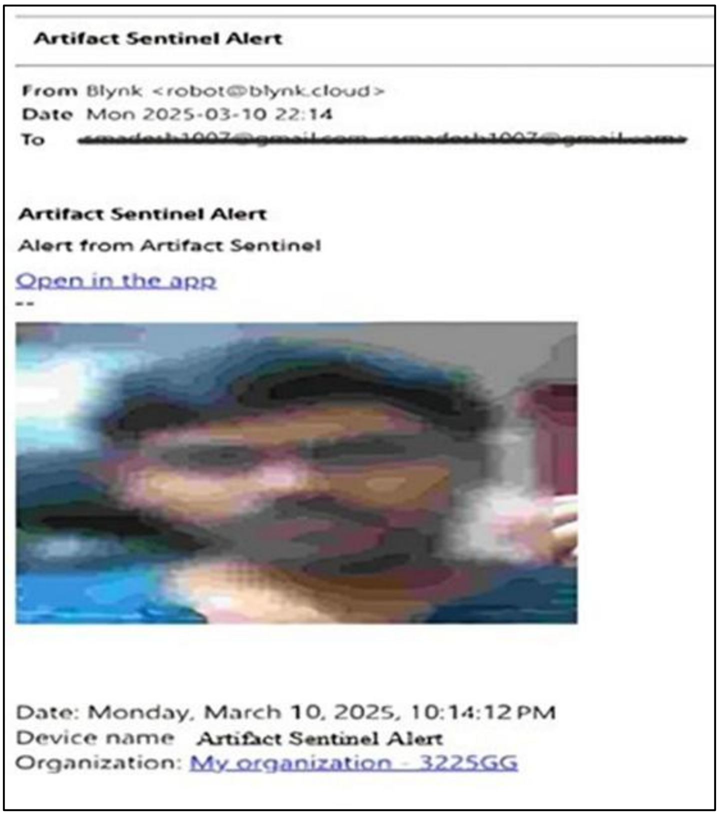

Figure 15. Alert Message

Table 3. Comparison with Existing Methods

Feature	Existing Method	Proposed Work
Environment and Motion sensing combined	Only one of this is found in each existing work	Both of these features have been implemented.
Alerts	Not all existing methods provide alerts.	Provides alerts to user.
Photo/Video Capture	Not all methods utilize camera	Camera used to take photograph of intruder
Integration to Museums	Low integration ability with museums	High integration abilities with museums
Power consumption	Moderate	Low

Deployment of the Artifact Sentinel system showed successful real-time monitoring and alert capability in security and environmental use. In testing (table 2), the motion sensor successfully detected illegal movement around the artifact and instantly activated the buzzer and alert notification system, allowing rapid response by security personnel. Comparison of the new approach with the existing approach is presented in table 3. Environmental sensors continuously monitored temperature and humidity levels, showing real-time readings on the LED display. When readings surpassed the safe limit, the system successfully sent alert messages (Fig 15), providing timely intervention. The findings validate the system's reliability in detecting and acting on potential threats. Besides, logging of sensor readings and alert events offers valuable information for long-term monitoring and preventive maintenance. Integration of these capabilities in one compact device streamlines the protection process and minimizes the need for human oversight. Overall, the Artifact Sentinel system is a useful and effective artifact security and preservation solution in museum settings

4.1 Key Elements of the Work

Three key features real-time motion detection, environmental element monitoring, and quick automated alerts were taken into consideration when designing "Artifact Sentinel." These fundamental characteristics support the preservation and protection of artifacts. The ESP32-CAM and PIR sensor enable the instantaneous detection of any unwanted movement in the proximity of the artifact, supporting the authorities' attempts to safeguard it. To keep the antiquities from deteriorating in adverse conditions and to aid in their preservation, environmental elements are regularly and real-time monitored. Lastly, the system uses Blynk IoT to deliver real-time warnings for quick response and an LCD display to show the temperature and humidity for simpler environmental element monitoring. By using a low-cost IoT-based solution to fulfill security and conservation needs, these features integrated into a single, small, and simple-to-install device constitute the main contribution of the proposed work.

5. Conclusion and Future Work

An intelligent internet of things-based solution for museum and remnant protection is the Relic Sentinel system. It optimizes safety by preserving the best possible storage condition for artifacts by combining speed, real-time alerts, and environmental monitoring. The system is a dependable and efficient method of protecting valuable objects since it can send information, take pictures of intruders, and display real-time environmental data. The evidence of deformation The sentinel tackles the shortcomings of the existing systems, such as their incapacity to monitor environmental conditions and detect speed, but it is unable to distinguish between authorized and unauthorized users, which is likely to result in undesired false positives. The problem will be resolved by using the AI model, and this system can grow in the future. For improved environmental control, integrating cloud-based databases can also result in remote monitoring and historical analysis. Large-scale museum communication can be further improved with Lura or 5G integration, such as wireless connectivity enhancement, leading to more robust and scalable security solutions.

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