The Future of Smart Buildings: Integration of IoT in Construction Engineering

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Abstract. Internet of Things isn't always approximately about the things themselves; it's approximately being clever. IoT is real and helpful because of its ability to apply intelligence to sense facts, especially in the context of construction engineering. A smart building's architecture is a great place to start as IoT is reshaping every aspect of a building, from design to occupancy to maintenance. The experience of workers, control, and tenants is being optimized through the use of IoT data to inform decision-making. Better facilities may simplify corporate processes and increase revenue in smarter homes. The goal of intelligent houses is sustainability. There are several methods for automating tasks with the Internet of Things. It is necessary to address every single facet of the building architecture. This article discusses the problems and technologies of IoT-based smart building architecture. The Internet of Things (IoT) and embedded systems provide the foundation of the "Smart Building" idea. Together with smart lighting in smart buildings and seismic detection, the model that is being shown has several features. When the smart lighting system turns on and off, it is determined by the amount of natural light available and the presence of people within the building. In order to reduce the amount of maintenance needed, smart dustbins that open up when they sense a person are available. Watering systems that are designed to measure the moisture content of the soil are extremely useful for the maintenance of lawns. A seismic activity detection module allows for early warnings of earthquakes and other seismic activity that may occur in the future. It has been successfully developed a smart building concept that uses Arduino and a cloud server to analyze the data gathered from the smart building.

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1 Introduction

Internet of Things (IoT) is a network of actual physical objects, like cars, appliances, and other items, that connect and communicate by way of electronics, software, sensors, actuators, and connections. Intelligent building automation and manipulation is getting a makeover thanks to the Internet of Things. The Internet of Things (IoT) can increase worker productivity and encourage the creation of novel services by upending long-standing business paradigms and offering vastly new options to improve building performance [1]. For the purpose of operating smart buildings, information and communication technologies are used in smart houses. When compared to the traditional method, they can reduce power consumption by improving productivity and beautifying architectural designs. Independent systems are seen in traditional constructions.

Automatization is a tool used in smart houses to improve construction performance and operations. In addition, by providing insight into its workings and useful data, smart designs enable human interaction. Additionally, they are able to connect with the strength grid, which is a feature that is becoming more and more important for software that calls for the deployment of reaction [2]. People are anticipating that as technology advances, numerous chores at home and at work will be automated. As technology advances, more attention should be paid to sustainable development to maintain a healthy environment. Because of technological advancements, the items in our environment are getting smarter these days. The latest paradigm in technology, the Internet of Things (IoT), is linking many devices to environment. An overview of several IoT technologies that are enhancing results on building sites are explained in the result section. The construction engineering sector has incorporated real-time information into processes that were previously not possible. IoT devices and sensors are gathering the necessary data on project sites, which is then processed, refined, efficient, and more cost-effective than in the past using traditional methods. These are starting to understand how important it is to introduce technology, particularly IoT. IoT will soon be ingrained in the daily operations of many businesses.

The fundamental component of the proposed model is the Arduino Uno, as everything happens in accordance with the actions that are stated in it. Plotting graphs on a server using the data gathered from the devices gives the user convenient access to information. The programming language used is Embedded C. An example of an IOT-based paradigm is the "Smart BuildingIn order to implement it, it adheres to the IOT system's three-step process [1]. As a result of the use of a variety of sensors, it gathers environmental data about the environment. In the modular construction of the soil moisture sensor, the information regarding the moisture content in the soil can be monitored and sent to Arduino for further analysis [2]. What data the Arduino transmits to the CLoud server depends on the moisture content

Depending on the needs, readings from the internet can be utilized to determine when to water plants. In the second section, an accelerometer that records the orientation continually is used to calibrate the value to a fixed orientation. When these statistics alter during an earthquake and there is a discernible difference, the system will sound an alarm to alert everyone in the region to the impending danger.

A smart trash can with an ultrasonic sensor to detect human presence is shown in the third part. The dustbin's lid opens to let people dispose their trash as soon as they reach out to it. Light intensity is detected by the LDR sensor and lights are activated based on what is detected. An ultrasonic module will be placed alongside this, which will turn off the lights if there is no one present. The complete set of data will be uploaded to the CLoud server, facilitating the plotting and analysis of related data, such as the frequency of earthquakes, the frequency of trash thrown, etc [3].

2 Internet of Things (IoT)

A network of linked computing devices is referred to as the Internet of Things (IoT) [1]. Included items are-human, digital devices, and mechanical machinery. Each of them has been given a unique identification (UID). The capacity to move data over a network without requiring communication between people or between people and computers. In essence, the Internet of Things is a network of different gadgets. This has to do with different kinds of software, electrical equipment and systems, and different kinds of network communication. These are meant for different kinds of information to be transferred, compiled, and exchanged. Numerous sectors have effectively used IoT, including banking, tourism, education, and telecommunications.

2.1 Architectural Trends and Objectives

IoT architecture consists of three main components, each of which has its own set of benefits:
Hardware: This includes embedded communication, interface circuitry, and sensor nodes.
Middleware: It includes resources for processing, analyzing, and storing data.
Presentation layer: This layer consists of effective visualization tools that work across several platforms and applications and provide the data to the user in a comprehensible format.[1]
The architecture of the Internet of Things is influenced by several variables. Consequently, present research efforts are concentrated on creating the optimal architecture to fulfill network requirements such as addressability, scalability, security, and efficient energy consumption. [9] It is anticipated that the number of devices connected to the network will rise in the future. Therefore, it needs to be accommodated in IoT design. Problem solving, energy usage, and scalability are all considered barriers to the successful application of IoT. Research is conducted to identify multi-hop, self-adapting routing systems that can cover a larger area and handle scaling issues.
There are three categories under which these can be classified:

1. A data-centric approach,
2. The use of location-based services and technologies
3. Hierarchical in nature [2].

2.2 Advantages of IoT in Construction [5]

- Real-time construction site inspection is made possible by IoT, making operational control simpler. IoT sensors on construction vehicles and equipment aid in their constant location and monitoring.
- Using IoT to locate and monitor materials and other resources will enhance scheduling and collaboration across various building project teams.
- IoT can produce data on the health of the equipment, guiding maintenance procedures to ensure prompt repairs and failure avoidance.

3 Challenges in Implementation

Property managers gets benefit immensely from smart buildings, but there are a number of security risks associated with the Internet of Things (IoT) technology that allows devices and homess to communicate. The security of employees, corporate information, and clients is becoming a top focus for property managers, who once had the most anxiety when an attacker entered the front door [4, 5, 6].

- Situations requiring a lot of data: The Internet of Things is all about data. The rising needs for statistics transmission, storage, processing, and intricate analysis truly overwhelm building managers. Understanding what hardware and software are needed is only the beginning; due to the sheer amount of information involved, operating the device to its maximum potential is a significant task.
- Knowledge and Skills: Building security and control professionals acknowledge their lack of Internet of Things knowledge and expertise. This lack of knowledge is a crucial and very significant factor in the adoption of IoT, since people who are unaware of the benefits of the technology are neither likely to approve financing nor be expected to handle the device.
- Cost is an ongoing consideration when considering new investments, but it becomes much more important when the return on those investments is not immediately apparent. Energy saving is more visible, but it's really only the tip of the iceberg when it comes to building IoT expenses. The advantages of this era affect all aspect of the business, and for those that showcase BIoT installations, the goal is to show decision-makers the whole cost over an extended period of time.
- Privacy: The gathering, storing, and use of personal information presents several privacy-related difficulties. IoT information is used to gather private facts, and organizations face privacy issues when the data they collect pertains to an individual's conduct. This is particularly challenging for buildings using Internet of Things (IoT) sensors, which by design sense user movement and analyze behavior to help facility managers make better use of their space.
- Security: One obvious and significant obstacle to the adoption of IoT is the fear of cyberattack. All parties involved in IoT must abide by stricter security regulations. Systems security requires adherence to appropriate security management procedures.

4 Results & Discussions

This proposed concept shows a model of a smart building with attributes including intelligent trash cans, sensors for measuring soil moisture, an earthquake detector, and an intelligent lightning system. In addition to being cost-effective, smart buildings are designed with environmental sustainability in mind. Although the initial cost of development may be 8–10% more than that of typical structures, the savings in energy usage can reach 30–35% [4]. It is easy to use and requires fewer workers. The extracted data is easily accessible because it can be seen from anywhere in the world. Home Wi-Fi is linked to the system as a whole [5–6]. The system refreshes the data on the server at regular intervals. Every user will be provided their ID and Passwords so that the user is always able to Enter his credentials to obtain the necessary information. A common channel for users is made.

Graphs are constructed using data that was collected through the Arduino IDE, which is an open-source application developed by Arduino.cc that enables the creation of code, construction of code, and upload of code to almost all Arduino modules. The data used for the graphs was collected through the Arduino IDE. After selecting the save channel option, the values are saved correctly. Some more tabs are supplied so that the necessary changes may be made in the channel. User can use the API keys tab to read and write data to and from the channel, accordingly. Depending on the needs, channel data may be imported or exported using the import/export tab. The plotted graphs are shown in the following images.

4.1 Smart Lighting System

As part of the proposed plan, this component aims to improve the efficiency of the system and reduce unnecessary current loss during the day. LDRs have been installed outside the building in order to accomplish this. In response to the amount of light outside, the LEDs inside the room will adjust their intensity in accordance with the amount of light outside. A second characteristic of the room is that there is a possibility that no one will be in the room at night if there are no people around. In order to verify the accuracy of the measurement, an ultrasonic sensor has been utilized. By using ultrasonic technology, the initial alignment of the wall with the ultrasonic unit can be calibrated. If there is an object blocking the view of the measuring instrument, the distance will be measured at a lower distance.

If this is the case, the user will receive a notification, and the lights will turn on according to the situation. Consequently, the lighting in the space will have a less intense intensity during the day as a result of this change. During the night, the lighting will change depending on the amount of light that comes from outside and how many people are in the room at the same time. In Figure 1 and Figure 2, you can see the graph and flow chart for the smart lighting system, respectively, as shown on the graphs and flowcharts.

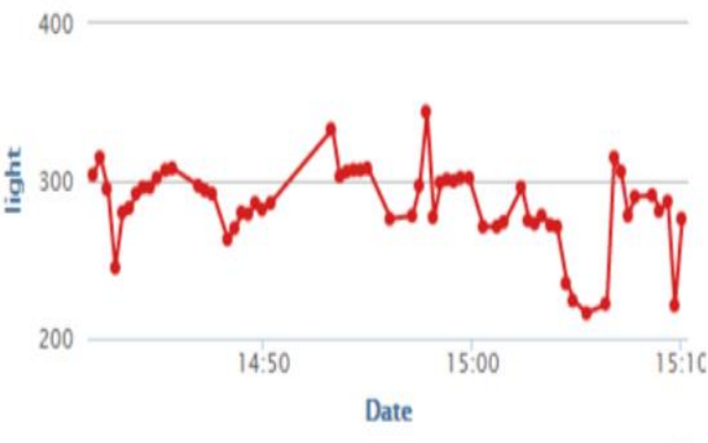

Fig. 1. Graph plotted for Smart lightning system.

Energy-Efficient LED drivers, sophisticated control algorithms, illumination sensors, and communication interfaces are all part of a smart lighting system, which consists of a network of interconnected lights. Fundamentally, the idea behind a smart lighting system is to provide a variable lighting setup that enhances both energy efficiency and visual comfort as shown in figure 1. Many smart lighting system implementations include various communication interfaces and extra features like real-time light spectrum reproduction and sophisticated detection options using illuminance and color sensors. Many functions beyond simple illumination are included in the newest lighting systems.

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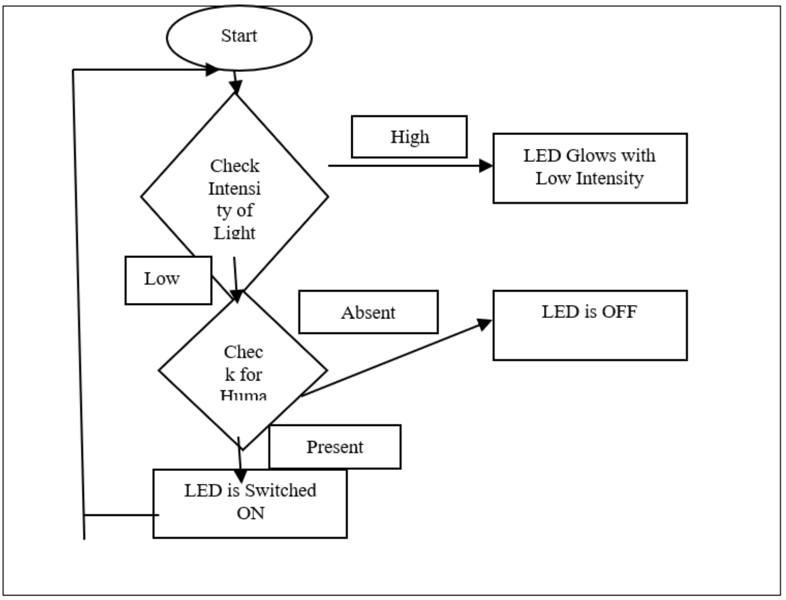

Fig. 2: Flowchart for Smart lightning system.

The idea is always evolving to meet the standards of the upcoming generation of Internet of Things (IoT) devices.

4.2. Earthquake Detection System

One totally unplanned type of natural calamity is an earthquake. It seriously harms both people and property. Although there is no way to halt it when it occurs unexpectedly, an alarm signal can be sent. Along all three dimensions, the accelerometer ADXL335 module is extremely sensitive to tremors and shakes. Thus, the seismic activity detected by this earthquake detecting system includes seismic vibrations. When mounted in the building, this module uses samples of the ambient vibrations to calibrate the values of the three axes each time Arduino turns on. To get true readings, the recorded values are then deducted from the actual readings. This calibration is done to prevent it from alerting you to typical ambient vibrations, such as those experienced when riding a train, etc. Arduino then compares the actual measurements with the maximum and lowest values that have been specified.

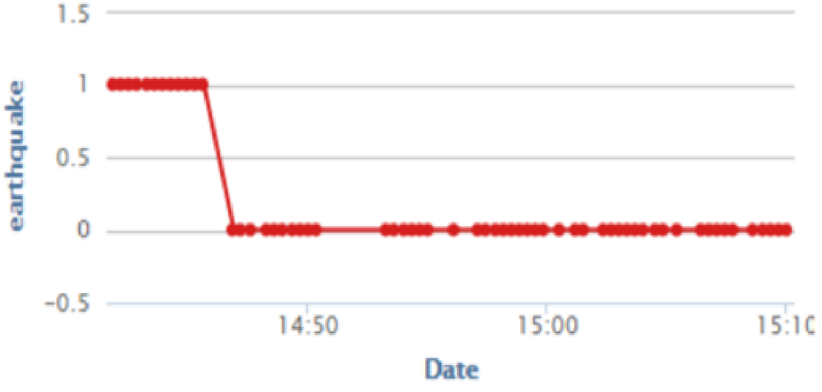

Fig. 3: Graph plotted for Earthquake detection system.

The buzzer sounds if Arduino detects changes in values that are greater or less than predetermined values on any axis, positive or negative. In order to change the sensitivity of the accelerometer, the predetermined values in the system should be altered. According to Figure 3 and Figure 4, respectively, the graphs and flow chart for the earthquake detection system are illustrated in Figure 3 and Figure 4.

In many ways, the software system of the built earthquake detection device may be responsible for the fact that a smart phone, smart watch, AI speaker, automated home equipment, as well as other nearby smart devices can all receive alerts about earthquakes this is due to the built in software system of the earthquake detection device. A seismic detection algorithm is triggered when the system detects movement over a predetermined acceleration level (e.g., 0.02 g), and it uses the acceleration data as input to execute an algorithm that detects earthquakes based on the acceleration data. Detection of earthquakes is based on dividing the input signal with a time interval of two seconds into earthquakes and non-earthquakes since the observed signals can be either earthquakes or false alarms from earthquakes.

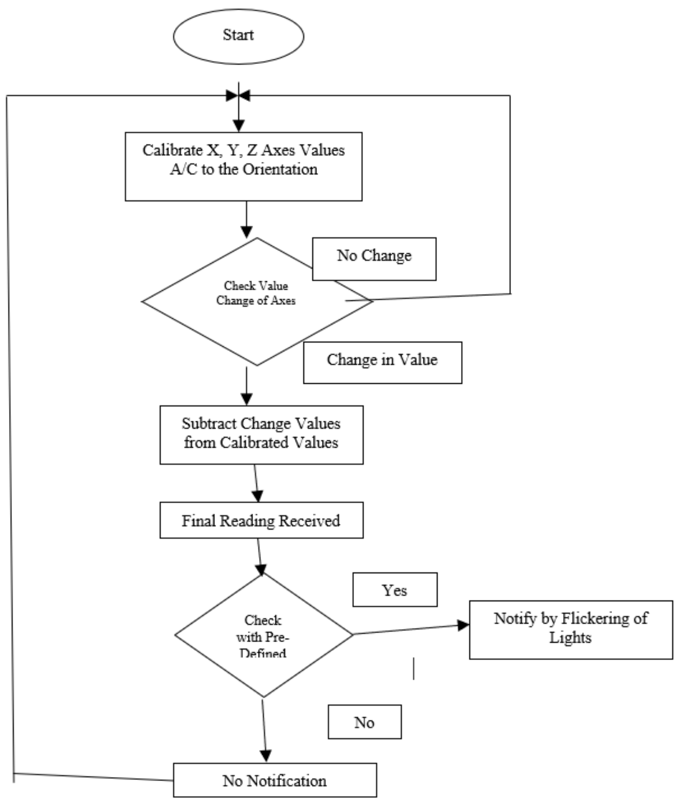

Fig. 4: Flowchart for Earthquake detection system.

4.3 Soil Moisture Measurement

This soil moisture sensor gadget uses an Arduino chip to alert users whenever the plants water content falls below the ideal level as well as a soil moisture sensor probing for identifying soil moisture. Down below a specific depth, the sensor is implanted in the soil.

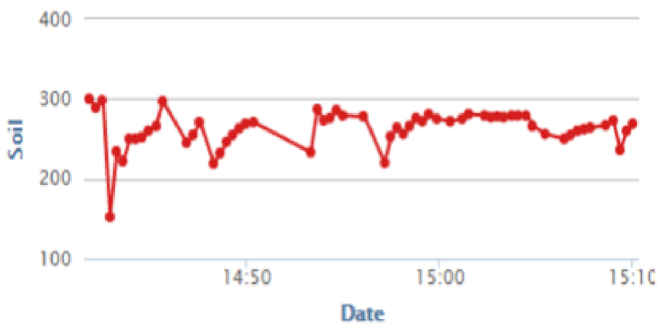

Fig. 5: Graph plotted for Soil moisture measurement.

All of the soil's dielectric constant is measured by the sensor, which sends out continual measurements. When values fall below an ideal range, the sensor notifies the plants to water. Figures 5 and 6 illustrate the soil moisture measurement graph and flow chart, respectively.

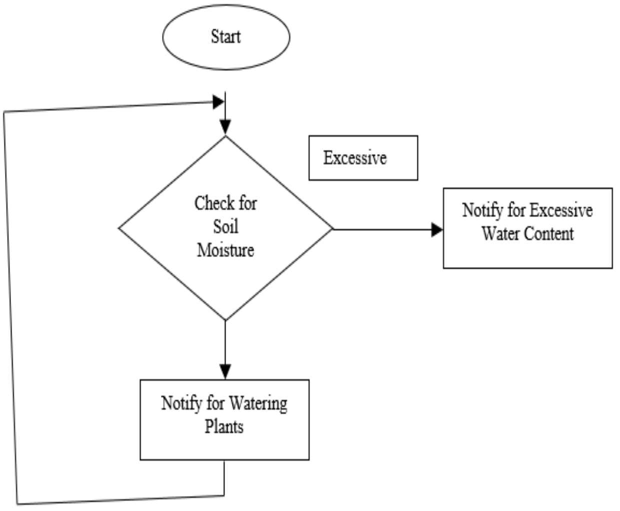

Fig.6. Flowchart for Soil moisture measurement.

In the near future, IoT sensors will be able to measure the temperature, nitrogen, phosphorus, and potassium levels, volumetric water content, photosynthetic radiation, soil water potential, and soil oxygen levels. After that, the data from the Internet of Things sensors is sent back to a central location (or the cloud) in order to be analyzed, visualized, and trendanalyzed. As a result of this process, it would be possible to optimize operations, detect patterns, and make small but effective modifications to condition to maximize output and quality as a result of the resulting data.

4.4 Smart Dustbins

The core concept is to use ultrasonic sensors to make regular trash cans intelligent. The front side of the dustbins has ultrasonic installation. The dustbin measures the distance from the wall that it is kept. The computed distance changes as soon as the individual arrives to discard the trash. The notice is delivered to Arduino as a result of this change in distance data. When the Arduino receives a signal, it instructs the servo. The servo action causes the lid to open. The individual can now discard trash inside. The trash can opens and stays open for three seconds before automatically closing.

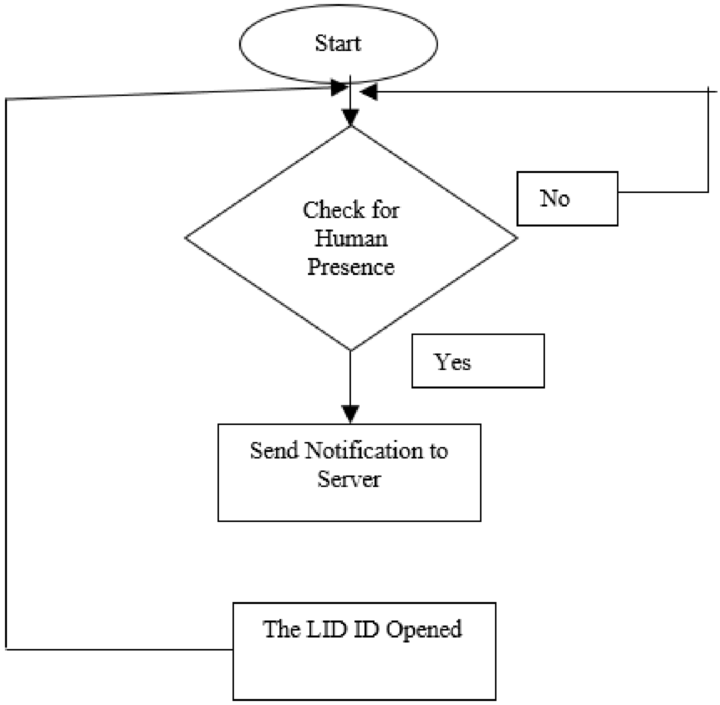

Fig. 7. Flowchart for Smart dustbin.

IoT-based smart dustbin is proposed in the above flowchart 7 that is integrated with different IoT sensors. The primary idea behind the proposed method is to build a smart way of handling waste, which is done by utilizing the IoT devices to wirelessly send the dustbin status that can produce a message on the Smart ID application. This message notifies the concerned person that the dustbin is full and needs to be emptied. The dustbin lid is automatically opened and closed on the detection of human hand. The Neo-6M sensor is used for tracking location of the dustbin and android application is built for the users to monitor the status of dustbin.

5 Conclusion

The use of the Internet of Things into architectural design and construction opens up new possibilities for meeting the needs of both developed and developing nations. It can be used to save money, improve accuracy, and for other particular purposes. If we wish to incorporate IoT into construction, our perception of the industry must change. This paper explains and effectively implements the notion of smart buildings. Compared to regular structures, smart buildings are more secure. The smart building is constructed with environmentally friendly materials and has an appropriate water management system. Smart building adoption is still very low, and more activities and improvements are needed before these technologies are used extensively.

Although the initial setup costs of smart buildings are greater, overall labor and energy savings add up to 20–25% of the total cost. Although the system complexity of smart buildings is a downside, this also makes the system easier for managers and users to utilize.

RFID technology and biometric authentication can be used to create smart buildings. Before allowing a person into the building, their fingerprints will be used for authentication. Additionally, relevant data on who enters and exits the building during the day will be provided to a server. This will raise the bar for security. Consequently, in the long run, the Internet of Things may have a big influence on architectural design and construction instruction. Future plans call for simulating modest building sites, evaluating smartphone usability, and extending the application to disaster management.

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