Assimilation of IoT sensors for Data Visualization in a Smart Campus Environment

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Abstract

Recently, various indoor based sensors that were formerly separated from the digital world, are now intertwined with it. The data visualization may aid in the comprehension of large amounts of information. Building on current server-based models, this study intends to display real environmental data acquired by IoT agents in the interior environment. Sensors attached to Arduino microcontrollers are used to collect environmental data for the smart campus environment, including air temperature, light intensity, and humidity. This proposed framework uses the system's server and stores sensor readings, which are subsequently shown in real time on the server platform and in the environment application. However, most current IoT installations do not make use of the enhanced digital representations of the server and its graphical display capabilities in order to improve interior safety and comfort conditions. The storage of such real-time data in a standard and organized way is still being examined even though sensor data integration with storing capacity server-based models has been studied in academics.

Keywords: IoT, smart campus, microcontroller, data visualization, sensors, augmented reality

1. Introduction

When it comes to the Internet of Things (IoT), context-awareness links the real and virtual worlds by using environmental sensors, network connectivity, and data processing approaches. Intelligent healthcare systems, intelligent transportation systems, intelligent energy systems, and intelligent buildings are all now possible due to the advancements in the Internet of Things. Sensor networks and smart IoT-based application services make up the unified architecture of IoT networks [1-5].

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As per the data visualization definition, an increasingly digital and networked world where physical items are also incorporated into the information network in order to gather data about the environment for smart indoor settings might benefit from the use of data visualisation. When it comes to the smart environment, this is particularly true, both inside (for example, showing data on urban accessibility in different sectors) and out (for example, designing infographics to raise environmental awareness). Regarding smart buildings, data visualisation is a useful tool for conveying information related to the IoT infrastructure and sensors installed in the building [6-10].

Smart services for many complex infrastructures are now being developed as a result of Big Data and IoT, working together. Big data technologies play a crucial role as visual analytics tools, delivering important information in real-time inside IoT infrastructures, aiming to assist essential decision-making. Many sensors in large-scale IoT applications result in a massive volume of data being gathered. Finding and analysing subsets and patterns of interest in the vast volumes of data accessible in IoT data analysis are two separate but related activities [11]. This article looks at how to use meaningful visualisations to derive insights from IoT data.

Visual analytics is a data mining, statistical, and visualization tool that may aid in the investigation of large volumes of data. With the help of interactive visualization technologies, users may take charge of the data analysis process and get crucial knowledge for making decisions. In order to see data from various angles and zoom in on specific aspects, the operator may interact with these proprietary data visualization tools. Machine learning and Artificial Intelligence (AI) are used in data analytics to find trends and generate predictions on their own [12, 13].

The goal of an energy audit is to learn how the building uses energy, who the users are, and what are the structure's structural and material characteristics that consumes the energy related projects. This procedure is concerned with gathering and analyzing a wide range of facts and information pertaining to a variety of subject matters. In order to conduct an efficient energy audit, one must be able to handle a significant volume of data of different kinds. Structure and organization are key to determining the building's energy profile and determining which retrofit scenarios are most suited. Existing buildings' digital twins still lack a coherent framework; despite new data capture technology and powerful modelling tools [14, 15].

The following sections comprise the content: related works are in section 2. The proposed work methodology is elaborated in Section 3. Its experimental observation is discussed in section 4. In the final section, the conclusion and possible future enhancements are discussed.

2. Related Works

The study [16] outlines a building indoor environment procedure for assisting social housing owners in their decision-making. Simulating different retrofit solutions based on

(a) The energy consumption reductions,

(b) 4D building indoor environment retrofit planning and disruption elimination,

(c) Cost simulation, is all done using building indoor environment.

Many areas of BIM and IoT integration are discussed in the current literature, such as energy management, construction activity monitoring, health and safety management, and building facility management, among other subjects. BIM and IoT interoperability research, on the other hand, are still in its infancy and theoretical in nature [17].

Sicat et al., (2018) created a toolbox for the immersive display of building data based on the Unity programming environment. A data visualization system integrated into the current system, was designed to display interactive 2D or 3D representations [18].

Using BIM, CFD, and VR, Hosokawa et al., created a virtual reality (VR) system to view the airflow rate and temperature of an HVAC system [19]. A knowledge-assisted BIM-based visual analytics method for failure root-cause identification was examined by Motamedi et al. Customized representations are provided by integrating BIM with other FM information (like inspection data) in the research [20].

Such visualizations let technicians use their cognitive and perceptual thinking to solve problems. Using BIM and thermographic pictures in conjunction with environmental sensing data, Natephra et al., suggested a technique for assessing interior thermal comfort by visualizing spatio-temporal thermal data on building surfaces. According to past research, before adding digital models into virtual worlds, preparing data is essential. However, there are presently no feasible ways to generate visualizations of live data streams for immersive settings [21].

3. Methodologies

3.1 Data visualization system

For existing structures with considerable architectural restrictions, this study's approach to real-time measuring and monitoring of environmental indicators, and energy usage inside the building is extremely creative. If this is the case, the monitoring systems must be simple to install and architecturally compatible with the building's design, as well as affordable, readily available, and manageable even by a non-expert user. In order to begin gathering data on environmental factors in real time, IoT sensors must be installed.

3.2 IoT Platform

The Internet of Things board, a well-known open-source IoT platform for data collection, processing, visualization, and administration, was chosen as the platform of choice. Using industry standard IoT protocols, it connects devices and enables both cloud and on-premises installations.

3.3 IoT infrastructures for indoor campus visualization procedure

One of the main goals of the proposed architecture for many sensors in the interior environment of data visualization, is to store IoT sensor data in capacity-based server models, and to visualize sensor information in a smart campus environment. Physical environmental factors impacting the interior environment may be measured and represented in real time using the suggested approach [22- 25]. Users and facility technicians both benefit from this feature since they can monitor interior conditions in real time as they move around the space. In addition, a marker-based localization mechanism is used for smart campus registration in this proposed system as various steps are noted.

Step 1

The proposed method makes use of appropriate virtual charts assigned to a specified creator to enhance the visualization of measured values of environmental conditions. Charts are shown on a real-world scene when markers are detected. The system relies on a server-based model already in place, as well as an immersive interior environment, to provide real-time data from several sources of real-time sensing [26-28]. To optimise the audit process, it was decided to construct a monitoring system that continually checks the interior parameters and the building's energy use.

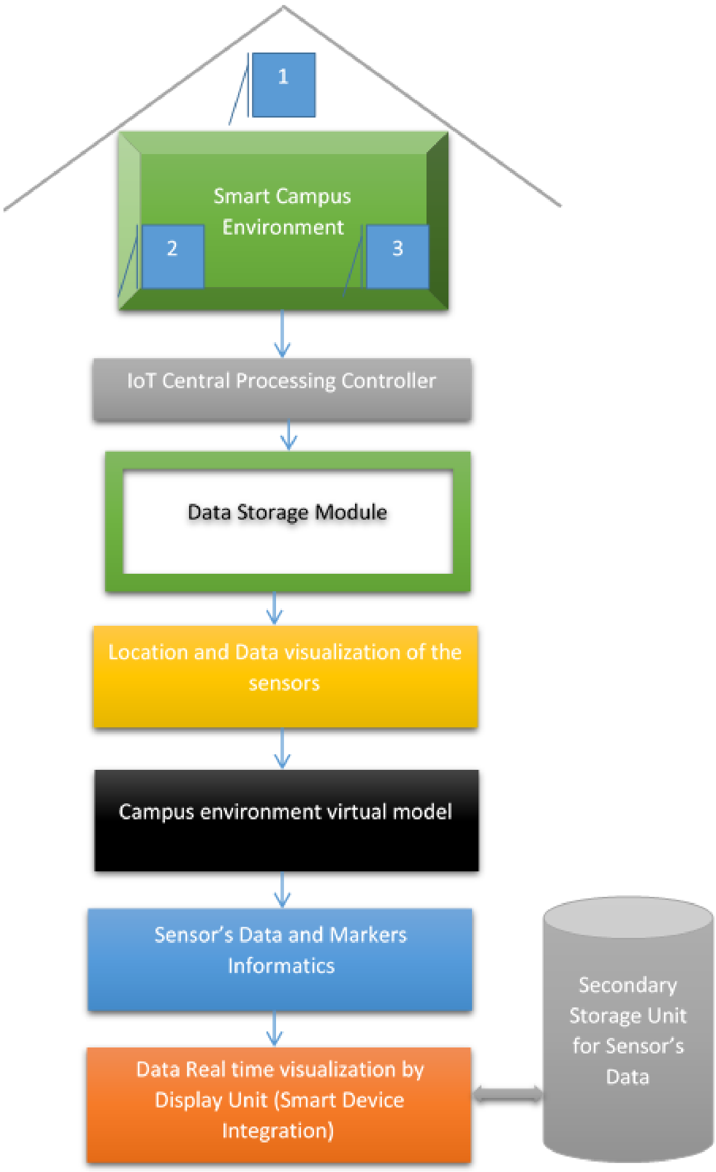

Figure 1. Overall proposed framework for data visualization at smart indoor environment

Step 2

A smart campus interior environment model of the facility is the next phase in which the markers are identified. Modeled features and sensors are placed in the same locations in the actual world as they appear in the model. In Stage 3, the model and position data of sensors are transferred to a smart campus environment in this step.

Step 3

Sensor readings are communicated to the memory-based server via an IoT controller, which is a microcontroller in this architecture, and saved in their database in the third phase.

Step 4

The fourth phase involves establishing a reliable link with the game engine so that sensor data may flow freely. This research makes use of the visual scripting capabilities of a certain gaming engine.

Using the established markers, the augmented reality experience may accurately register virtual charts. To conclude, a smart campus environment's application on a portable device displays the live sensor data and the interior thermal comfort evaluation results. The suggested approach then automatically stores the sensor data using a visual programming environment for smart campuses called Dynamo. Marker positions are finally transmitted from a large number of memory-based models to the game engine [29]. The Unreal Engine's visual scripting allows sensor data to be tied directly to the game world. The created tool is used to manage the game engine's live sensor feed.

Step 5

On the fifth stage, the data from the sensors are displayed in the smart campus. Real-time sensor data plots are shown in data visualization agents using virtual charts built for this purpose. The camera must be able to clearly see the markers in each room in order to create virtual charts. After that, the system determines the smartphone's position and orientation in relation to the identifier and displays the corresponding virtual chart. Using the charts in the interior environment, users may statistically study and assess the environmental conditions and the indoor thermal comfort. Figure 1 depicts the sensor numbers used to find indoor environment in different locations, with numerical values representing the sensor numbers. There are three sensors (named 1, 2 and 3) linked and installed in a smart campus environment: sensors for measuring temperature, humidity and light intensity [30, 31].

4. Results and Discussion

The Arduino Uno microcontroller is used to link the smart campus environmental sensor modules. Other features include digital outputs of the interior environment's humidity and temperature, which is managed on a regular basis. The code that will run on the actual board is written in the Arduino Integrated Development Environment (IDE). The Arduino IDE already has a number of libraries that may be used to gather information such as humidity, temperature, and more. In this experiment, the sensor's pin signal was attached to an Arduino digital port to read data from the sensor.

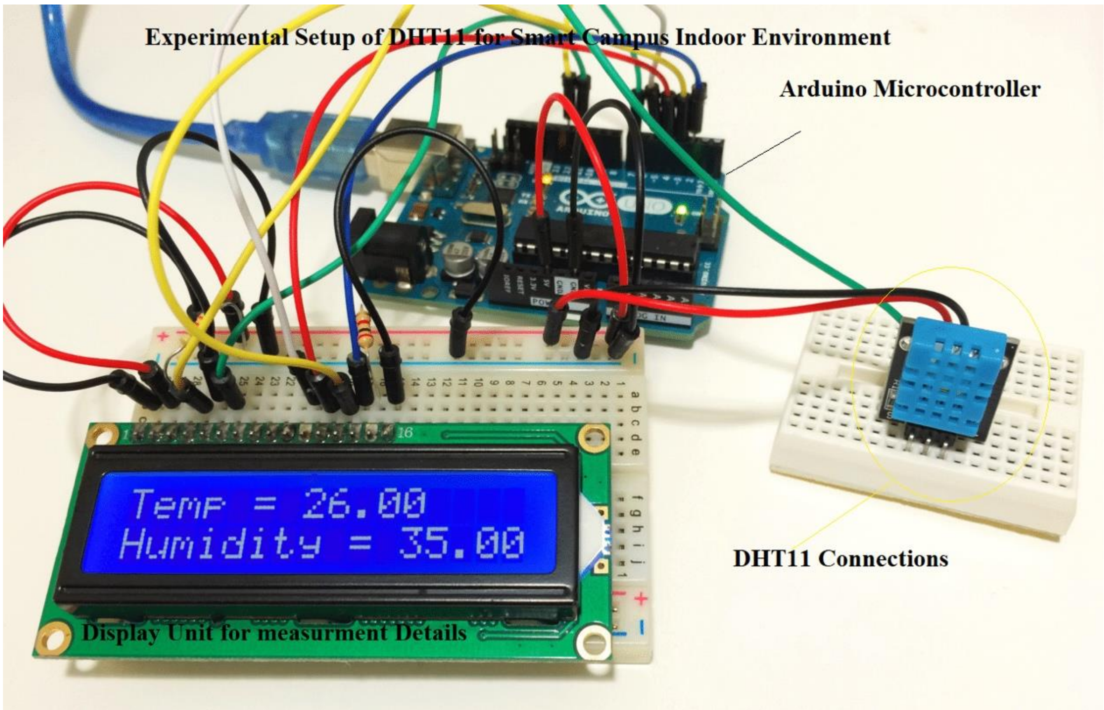

Figure 2. Real-time experimental setup with DHT11 devices

The saturation point varies with the temperature of the surrounding atmosphere. The real time compares hot and cold air, that the latter holds a lot more water vapour before being saturated. Because of this, the formula for determining relative humidity is as follows:

$$Relative\ humidity = \left[\frac{Desity\ of\ water\ vapor}{Density\ of\ water\ vapor\ at\ saturation}\right] * 100\%$$

In this study, photoresistor sensor modules are mounted on Arduino boards to assess light intensity. The obtained experimental results have been tabulated in table 1. The brightness of the illumination was measured using analogue pin "A0". Once the Arduino boards have been programmed with the generated code, the sensors begin collecting data for use in smart indoor environmental monitoring. The obtained and monitored data are stored at memory unit that is shown in table 1 with observation.

The Arduino has a built-in technique for linking sensor readings to a memory storage device. The first step is to connect the DHT11 and photoresistor sensors to the Arduino board. Environmental measurements, such as air temperature, humidity, and light intensity, were gathered and presented on the serial monitor console of the central unit after uploading the generated code onto the board. The graph has shown temperature and light intensity output from the sensors' data. Using the whole dataset for the smart campus interior environment, it is discovered that both are directly proportional to one another.

Table 1. Observation from experimental setup's results

Time Range	Temperature (°C)	Humidity	Light Intensity (lux)	Changes	Observation
(9:00-11:00AM)	28	40	148	No	Transferred sensor data from Memory to System Excel Sheet
(11:00AM-1:00PM)	28	40	150	No	Transferred sensor data from Memory to System Excel Sheet
(1:00-3:00PM)	29	41	152	Yes	-bit delay in transferring sensor data-
(3:00-5:00PM	28	41	151	Yes	-bit delay in transferring sensor data-

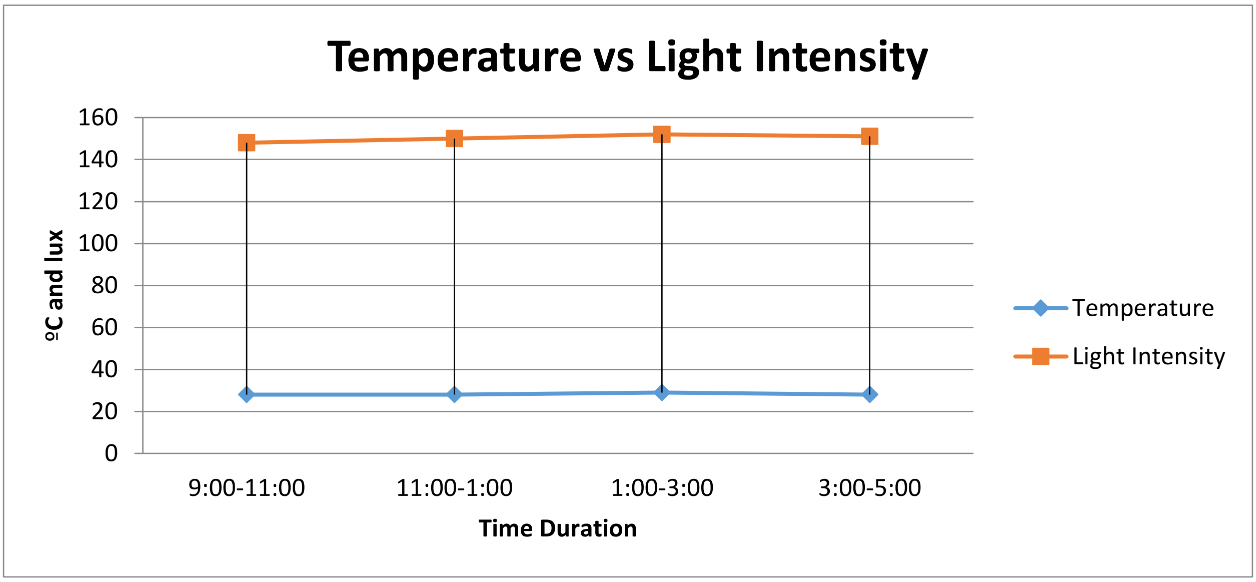

Figure 3. Experimental results observation

A firefly is utilized to communicate sensor data from the Arduino Uno to the memory-stored system using Dynamo, a visual programming tool. "UE4Duino2" is used to connect Arduino sensor outputs to the Unreal Engine. The Arduino data may now be retrieved in real-time using this plugin for Unreal Engine 3 to excel sheet in the personal computer. In the last step, the Unreal Engine is used to construct the user interface for displaying sensor data in augmented reality. It has also been noticed from Table 1 and the graph that, when the temperature at the margin point changes, data transmission is somewhat slower for other operations.

5. Conclusion

The real-time issue identification is possible due to the proposed method for assimilation of sensors data storage of smart campus indoor environment. The real-time sensors readings database may be used to record information about interior environmental conditions for subsequent analysis of historical data about the facility's indoor needs. Environmental-based condition monitoring and Internet of Things infrastructures are combined in this study. Furthermore, data visualization techniques are supplied to protect campus safety and increase sustainability. The data acquired during the first year of deployment will be used to develop a machine learning module for the online application, which will propose timetable changes to increase campus sustainability and safety, in the future.

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