Webar Application For An Air Quality System In IOT-Based Smart Environement

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Abstracts: Augmented Reality (AR) and the Internet of Things (IOT) are trending technologies that have gained popularity in smart cities. In this paper, we propose a non-expansive and uncomplicated prototype that combines the two technologies, namely, the Internet of Things and Augmented Reality, to build an air quality monitoring system for a smart environment. The webAR application developed can be used on any device, and it control measurements of temperature, humidity, and air quality data collected from multiple IOT devices. In addition to the ease of use and speed of loading compared to other applications, our prototype offers an application that does not require installation, a major factor that limits user use. Finally, the paper indicates the prospects of these technologies and the challenges their development is facing.

Keywords— Smart City, Smart Environment, Augmented Reality, Internet of Things, sensors, WebAR.

1. INTRODUCTION

Better and comfortable life is the aspiration of every human. Owing to advances in science and technology, not only an average human lives longer, he/she also lives more healthier than before. Most of the contemporary applications of technology are concentrated in urban areas. That is why there has been a greater appeal to live in big cities. As per United Nations, more than half of the global population reside in big cities and this percentage will further grow in next few decades [1]. Such enormous and continuous migration towards megacities will be challenging for the government for a number of reasons. The residential, economic, health, transportation, and environment infrastructure of the megacities needs to be upgraded to cope with this. In addition, to increase and improve the infrastructure that is already present, another and at times more viable strategy is to use the existing resources more efficiently and smartly. The concept of smart city is based on the idea that cities should be sustainable in financial and environmental aspects. Moreover, such smart cities will also be an offer with better and improve quality of life. The number of present-day cities, which are transforming themselves in to smart ones are growing, particularly, in the developed world [2].

The application of artificial intelligence (AI) can help cities become smart. The AI-based applications can be very helpful in the efficient use of energy resources, timely and sustainable disposal of city's waste, environmental impact of the city's population, inoculation of contemporary trends in the city's education system and many more. Furthermore, the AI can help gather the crucial data about the city's population and about the interests of the city's population. Such data is extremely important to devise present and future strategies for the smart city [3]. Artificial intelligence is also inculcated into almost every domain of human life. At what time the public transport will arrive at our stop? What will be whether life today? The suggestions shown by our search engine regarding sales of our favorite brands. All these somewhat trivial, yet so important tasks of the day owe themselves to AI. So much of the data about us and our surroundings is collected to devise techniques to further improve and enhance the human life experience. Internet of Things (IoT) is described as the interconnectivity of numerous physical devices via the internet, enabling them to communicate with one another and sharing data without the need for human intervention [4]. Such devices include, but not limited to, sensors, routers, and other electronic devises [4]. Such communication between connected devices is aimed to improve the quality of human life. The ability to bring together the digital and physical world has made it popular in the development of smart cities. It has made it possible for physical devices to be smart and become readily responsive. The smart cities will be economically, socially, and environmentally sustainable [5].

The development of Augmented Reality (AR) technology has enabled people to virtually interact with the real-world environment using perceptual information being digitally overlaid [6]. This concept is based on the technology that involves overlaying computer-generated images, so that the virtual world is almost aligned with the real world [7]. Such virtual images can not only be seen, but they can also be interacted as well, significantly enhancing the users' experience. The early application of AR mostly relied on the use of head-mounted displays (HMD), however, in the last few hours, the AR has expanded to hand-held devices and advanced hardware and software. This, not only have increased the number of applications using AR, but also the realm of applications of AR. In one study, the AR was used to train amputees for using the myoelectric prosthesis over the standard rehabilitation techniques [8]. In another similar study, the users were taught about how to move the upper body muscles and as per participants, they preferred the AR system [9]. One of the most classic examples befalls a person in a hotel room who needs to raise the temperature of the room. If he cannot find the thermostat, then he uses AR to connect to any IoT devices and the room will be visible through AR where the client can subsequently raise the temperature virtually [10].

The two technological developments have become the most common conversation right now. The overlay over actual objects and devices offers swift visual feedback without the need to search or operate with hands. The combination of AR and IoT is revolutionizing the interactions with ingenious devices, where the AR provides a way to control and view the data and information of various devices and objects in each environment. In concrete, the IoT enables devices to communicate and exchange relevant information. The IOT and AR can facilitate the digital interaction between the physical and remote conditions. For example, an AR-based view of the environment can be helpful for engineers in poor visibility and other hazardous environments [11]. An important aspect is the difference between virtual reality (VR) and augmented reality. The VR empowers the user to exist in the virtual world, while the AR merely enhances the user experience while still being in his host environment.

1.1 RELATED WORK

In article [12], the author used Augmented Reality to control various devices connected via IoT using gestures. It enables users to eliminate the need for mobile applications or web applications to control the devices. The AR technology on a mobile device has been coupled with IoT to create a system able to maintain supervision, view information, and offer training services in a building environment regarding energy devices [13]. This way, they can monitor power consumption, energy usage for various devices, and respond swiftly to energy issues because of the real-time data provision from the system. These technologies have also been used in the development of learning platforms where a 3D learning game is used to generate real-time images and models to help students visualize what they are learning [14]. [15] describe a building management model being incorporated with AR and IoT to monitor the indoor environment by collecting relevant interior data regarding such factors as lighting and humidity and displaying it in an AR system. It has also been used to develop an interactive energy management system that can easily monitor energy usage in urban and modern smart cities without the need to interpret graphical and statistical data in computers [16]. They have also been incorporated in energy-efficient schools where sensing devices are built in and used to monitor energy usages through AR and using IoT to monitor and service the various devices [17]. [18] describe a combined system using the technologies of AR and IoT to illustrate a human-city interaction where people can virtually access such services as shopping, traffic systems, and social amenities among other services from the comfort of their homes.

With respect to the health sector, the AR application proposed in this study emulates the beating heart of the patient, in order to improve the patient-doctor interaction [19]. Another study combined the aspects of IOT and augmented reality to help caregivers get notified about the status of the patient and to help the patient using smart glass and receive information in the form of audio or text signal [20]. Another application of AR is reported for patients going through rehabilitation. The system comprises of serious game and a wearable sensor network to improve the engagement of patients during the rehabilitation process [21]. With respect to the environment, a study reported an AR-based prototype of the bicycle that with the use of IOT, can promote and encourage the bike-sharing concept in a community [22]. Another study combined the IOT with AR for the measurement of air quality and other environmental factors. The study ekoNET solution and data was visualized on handheld mobile devices [23]. To make cities sustainable, energy conservation is vital. In this study, the AR is used to represent the real-time energy consumption of appliances at the home. Moreover, the system also allowed to interact with the appliance using IOT. Hence, the monitoring and control, both options were provided by the system [24].

The AR-based applications can be divided into two broad categories. The first category involves using a marker-based augmented reality, which focuses on a marker or a landmark and then further tracks its spatial features using camera. The examples of marker-based augmented realities include QR codes, product packaging and logos. Second category of AR-based applications involves using GPS and accelerometer features of the cell phone and using the location-based data to extract spatial features. Moreover, this type of AR-based applications include google maps and Pokémon go [25]. Moreover, the marker-less AR based applications need strong and powerful tracking and pattern recognition algorithms to render them effectively with users' data. The advantage of marker-based AR application is that it is easy to implement, however, the marker-less applications are more interactive and powerful.

A number of studies have suggested a system for the monitoring of environmental parameters like temperature, humidity, and air quality. In this study, the temperature is measured using a sensor and then based on the reading the window operation is automated. The temperature is measured using DHT11 sensor, however, no other parameter is measured and moreover, except of the intervention based on the temperature readings, the user is not allowed to interact with the system [26]. In another study, using MQ135 sensor, the authors have monitored the quality of ambient air. This sensor measures quite many gasses, including ammonia, alcohol, smoke, and carbon dioxide. Based on the reading of the sensors, the data is translated to whether the air quality is good or not. This system too did not give user the ability to interact and also the measurement was only limited to the different gasses [27]. Moreover, the concentration of air particulate is also a good measure of the air quality. Another research study have developed system that can measure the $PM_{2.5}$ and PM_{10} particulate concentration in the air, however, it again only monitors that concentration and any interaction from the user of subsequent intervention is missing [28]. We believe that there is a need of a smart IOT-based, and cost effective, air quality monitoring system, that can detect different gasses along with temperature and humidity. Moreover, such monitoring should be extended to user interaction using augmented reality and lastly, user should be given with this ability to intervene and take necessary action in real time.

1.2 PRODOSED SYSTEM

To overcome the research gap identified in the previous section, in the subsequent section, we will propose a system that can be used to effectively monitor smart environment sensors, in the context of smart city. Our proposed system will not only measure the temperature and humidity, but it will also measure the concentration of different gasses including Ammonia (NH3), sulphur (S), Benzene (C6H6), CO2, and other harmful gases and smoke. The micro-pollutants in home environments are usually minimal, so measuring them would not be needed. Our proposed system will use wi-fi module to communicate the air quality parameters to ThingSpeak IOT platform, and finally, visualize the data with an easy webAR application.

1.2.1 System architecture

The framework proposed is made up of sensors, AR system, and an IoT platform, all in collaboration to help monitor air quality usage for a smart environment. It contains DHT11 (Figure 3) and MQ135 (*Figure 4)* sensors, *ThingSpeak* IoT online platform, and an Augmented Reality application all working in conjunction to help collect, store and display the data and information from the sensors. The sensors used are cost inexpensive and are IOT-compatible. Fig. 1 shows the interactions between the components of the system.

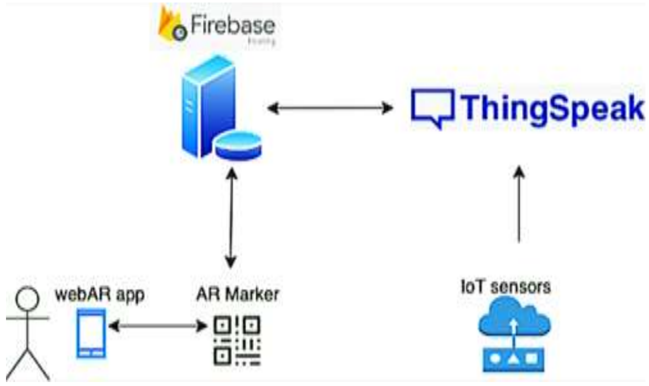


Fig. 1. The complete framework of the proposed system.

The ThingSpeak communicates with both IOT sensors and the cloud network, which ultimately conveys information to the webAR app The detail of the interactions between the components of the system and the role of each is described briefly below:

DHT11 and MQ135 sensors (connected to Arduino) collect data pertaining to temperature, humidity, and concentration of various gases.

- Data collected are sent to the ThingSpeak system through using Esp8266 Wi-Fi module.
- ThingSpeak receives and updates data of the API.
- When user scans the AR markers with the webAR application, it shows a real-time and history data visualization of temperature, humidity, and gas concentration.
- The data are shown in a as values and graphs on the mobile AR application.
- When values of air quality are anormal, alerts are sent and shown in the application.

To better understand the sequence of exchanges between components, a sequence diagram is shown as below in Fig. 2.

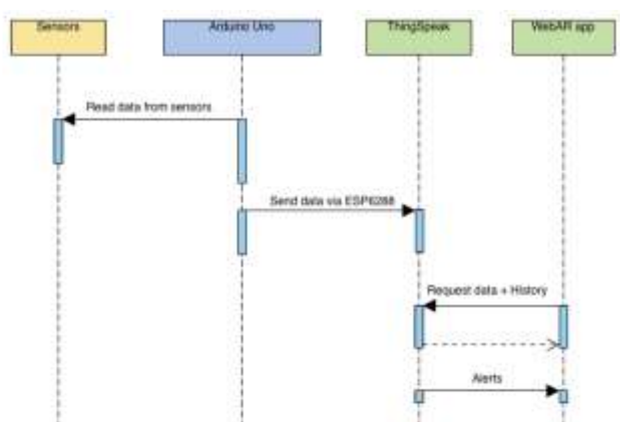


Fig.2. The sequence diagram of the system.

1. The Arduino module reads the data from the temperature and humidity sensors.
2. The ESP8266 (Wi-Fi module) retrieves the sensor data from the Arduino.

3. The ESP8266 sends the temperature and humidity data to ThingSpeak via Wi-Fi link.
4. The augmented reality app on the mobile phone sends a request to retrieve the temperature and humidity data from ThingSpeak.
5. ThingSpeak returns the temperature, humidity, and gas concentration data to the webAR app.
6. ThingSpeak send alerts if values of air quality are abnormal.

2. Material and methods

In this section, the various sensors and communication modules that are used in our design are described. We used Arduino as a microcontroller along with the Wi-Fi module for wireless communication. The temperature/humidity and concentration of gasses were measured using DHT11 and M135 sensors.

1) DHT11 (temperature and humidity sensor):

Temperature and humidity levels are measured using the DHT11 sensor. These sensors have two elements that help them in measuring capabilities. These elements include a thermistor to test for temperature levels and a humidity sensing capacitor for measurement of humidity levels. This sensor can measure temperatures ranging from 0 to 50 degrees Celsius [29]. The variation in reading is ±2 degree Celsius, rendering this sensor reasonable accuracy. On the humidity side, it has a 5 percent accuracy and a range measure of 20-90 percent humidity [29]. The miniature size of the sensor makes it easy to be incorporated and interfaced with any microcontroller. This way, it can be useful in measuring ventilation, the level of heating in an environment, or even the air conditioning of a given room.

2) MQ135 (Air quality sensor)

MQ135 is another miniature sensor that can be used together with microcontrollers to detect various gases for air quality control. The sensor has a low conducting capability across clean air but high conductivity in gasses such as carbon dioxide, ammonia, and smoke [30]. These sensors are also fitted with analogue or digital outputs like LED indicators to make an alert when a high level of conducting gases is sensed in the air. This makes it easy to spot leakage at an instance.

3) Esp8266 Wi-Fi module:

ESP8266 is a Wi-Fi module with many applications, especially in the field of IoT. It is a networking device acting as antennae to enable internet connections to routers [31]. It is also useful as a data processing device where it analyses the data collected from a set of analogue and digital sensors. It comes with a small on-board microcontroller of its own too. It can also offer connectivity of two devices in a protocol known as peer-to-peer for devices under the internet. Finally, it can also be used to access various web pages on the internet that can act as web servers. It can be incorporated in such devices as locks, cameras, and smartwatches among other devices. This device is found in various forms of chips, modules, or boards according to purpose [31].

4) Arduino microcontrollers:

The Arduino is an open-source multi-purpose microcontroller, that can be programmed, and it has seen an exponential growth as a basic component in development of electronic solution [32]. The schematic of Arduino UNO is shown in Fig. 3. Some of the main components present on the Arduino board are described below,

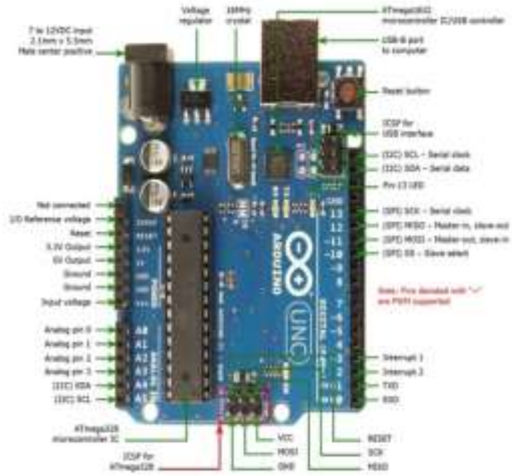


Fig.3. The Arduino UNO microcontroller.

5) IoT platform: ThingSpeak:

ThingSpeak is an IOT analytics platform that has the capability to view and analyze the incoming data in real-time. Moreover, user can intervene with all connected devices simultaneously. It is an open-source Internet of Things (IoT) application utilizing REST APIs in its usage [33]. The *ThingSpeak* enables the creation of sensor logging, location tracking, and web services [33]. It also has the capabilities of self-customization through additional plugins in the interface. It is relatively easy to set up *ThingSpeak* application and create a channel to which you add fields where connected sensors will send their data. For the communication different data forms (CSV, JSON, XML) are supported, we choose a JSON format for storing and transporting data.

6) Augmented Reality technology used

To build the AR application, we choose develop a webAR application with A-Frame framework and the AR.js. A-Frame is an open-source web framework for creating VR and AR experiences using HTML and JavaScript, while Three.js is a lightweight library enabling AR feature development of web-based AR experiences.

Using AR.js and A-Frame for a webAR application, instead of a native AR application developed with Unity offers several advantages, enhancing the user experience and accessibility of the smart environment monitoring system. Table 1 shows a comparison between the two approaches.

Firstly, AR.js and A-Frame enable web-based AR applications, allowing users to access the experience through their browser, eliminating the need for app installation, and ensuring compatibility across devices.

Secondly, these frameworks are built on open web standards, encouraging cross-platform support and providing a more lightweight solution compared to *Unity*. This results in faster loading times and potentially lower resource usage on users' devices.

Lastly, the development process with AR.js and A-Frame is streamlined and more accessible, enabling rapid prototyping and easier deployment of updates, ensuring that the smart environment monitoring experience remains current and relevant. Table 1 shows comparison between the 2 approaches

Table 1. Comparison of the 2 approaches of AR implementation

Aspect	WebAR app (AR.js & A-Frame)	Native AR app (Unity & Vuforia)
Accessibility	No installation needed (web browser)	App installation required
Compatibility	Cross-platform support	Platform-specific

		development
Resource Usage	Lightweight, faster loading times	Higher resource usage, slower loading times
Development Process	Streamlined, rapid prototyping	More complex, longer development cycles
Updates Deployment	Easier, directly to the web-based app	Requires submission through app stores
Open Web Standards	Built on open web standards	Proprietary engine and standards

3. IMPLEMENTATION AND SYSTEM DEVELOPEMENT

3.1. Setting up the hardware components:

To setup the hardware components, we start by bringing together and incorporating the hardware elements, linking the MQ135 and DHT11 sensors to the Arduino Uno, and establishing communication between the Arduino Uno and ESP8266 module. Our goal is to create a seamless connection between these components, ensuring accurate data collection and efficient data transmission.

3.2. Sensor integration with Arduino Uno

In this part, we connect the MQ135 sensor for air quality measurement and the DHT11 sensor for temperature and humidity to the Arduino Uno. We then code to collect and process the sensor data, allowing the Arduino Uno to interpret the information accurately. The code used to read temperature, humidity and air quality data from sensors and print the values on the Serial Monitor, is given below in Fig. 4.

```
#include <DHT.h> // Include DHT library
#define DHTTYPE DHT11 // Define DHT11 sensor type
DHT dht(DHTPIN, DHTTYPE); // Initialize DHT sensor
#define MQ135PIN A0 // Define MQ135 data pin
int sensorValue = 0; // Initialize sensor value variable
float R0 = 76.63; // Define MQ135 R0 resistance value
void setup() {
  Serial.begin(9600); // Initialize serial communication
  dht.begin(); // Initialize DHT sensor
}
void loop() {
  float h = dht.readHumidity(); // Read humidity value from DHT11
  float t = dht.readTemperature(); // Read temperature value from DHT11
  sensorValue = analogRead(MQ135PIN); // Read air quality value from MQ135
  float Rs = (1023.0 / sensorValue) - 1.0; // Calculate MQ135 sensor resistance
  float ratio = Rs / R0; // Calculate ratio of MQ135 resistance to R0 resistance
  float ppm = pow(10, ((log10(ratio) - 2.63) / -0.37)); // Calculate air quality ppm value
  Serial.print("Humidity: ");
  Serial.print(h);
  Serial.print("% Temperature: ");
  Serial.print(t);
  Serial.print("C Air Quality: ");
  Serial.print(ppm);
  Serial.println("ppm");
  delay (5000); // Wait for 5 seconds }
```

Fig.4. The Arduino UNO microcontroller.

3.3. Connecting ESP8266 to the Arduino Uno

We establish a communication link between the Arduino Uno and ESP8266 module by connecting them through the appropriate pins. We program the ESP8266 to receive data from the Arduino Uno and ensure that data transmission occurs smoothly and without loss. For example, we use the SoftwareSerial library to enable communication.

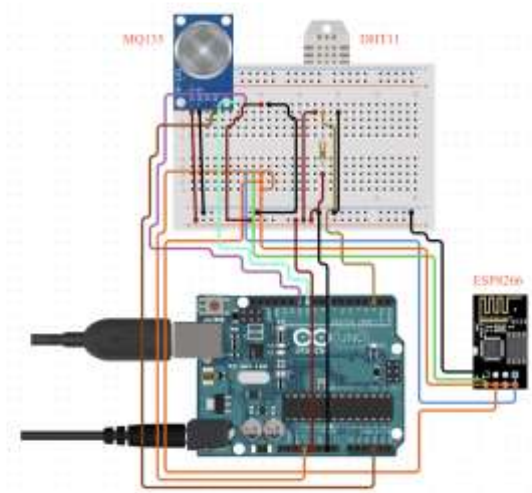


Fig. 5. Connection Diagram of DHT11 with ESP32

3.4. Configuring ThingSpeak

To view and analyze the incoming data in real-time, we create a channel in *ThingSpeak* and configure the ESP8266 to send sensor data, ensuring real-time data visualization in the AR application. We set up channels, assigned field names and API keys, and create a channel with fields for temperature, humidity, and air quality (Fig 5). This channel allows for organized data storage and ensures a seamless connection between the ESP8266 and *ThingSpeak*.

For ESP8266 connection with *ThingSpeak*, we used the provided API keys, we establish the communication frequency and optimize the code for efficient data transmission and minimal latency.

Fig.6. Data shown in ThingSpeak platform.

3.5. The webAR Application

In this part, we explored integrating IoT data with augmented reality. We developed an application using A-Frame and AR.js that fetches real-time data from *ThingSpeak*. With a custom JavaScript function, we retrieved the sensor data and displayed it on an AR marker. This seamless fusion of IoT and AR allows users to visualize and interact with the information in a highly immersive and engaging manner, opening up new possibilities for data visualization and contextualization.

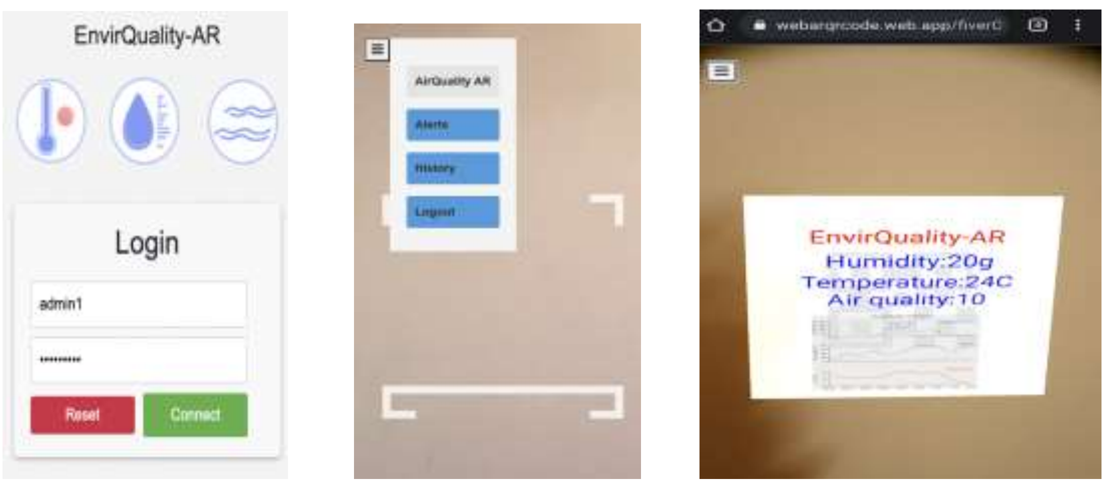
First, we establish a new project by incorporating the A-Frame framework and the AR.js library. This combination allows us to create a captivating 3D scene that includes AR markers to represent the temperature, humidity, and air quality data. Next, we develop a script to fetch the relevant data from *ThingSpeak's* API using our channel's API key. Once the data is successfully retrieved, we dynamically update the 3D scene to reflect the latest sensor readings. The project is hosted on Firebase for easy access and interaction with our AR application.

Here is the main JavaScript code (Fig. 6) used to fetch data from *ThingSpeak*

```
<script>
    const channelId = "2112680";
    const apiKey = "WBLESM01D45Z2PH5";
    const fieldNumbers = {
        temperature: "1",
        humidity: "2",
        airQuality: "3",
    };
    function fetchData() {
        const url = `https://api.thingspeak.com/channels/${channelId}/feeds.json?api_key=${apiKey}&results=1`;

        fetch(url)
            .then((response) => response.json())
            .then((data) => {
                const feed = data.feeds[0];
                const temperature = feed[`field${fieldNumbers.temperature}`];
                const humidity = feed[`field${fieldNumbers.humidity}`];
                const airQuality = feed[`field${fieldNumbers.airQuality}`];

                document.querySelector("#temperatureData").setAttribute("value", `Temperature: ${temperature}°C`);
                document.querySelector("#humidityData").setAttribute("value", `Humidity: ${humidity}%`);
                document.querySelector("#airQualityData").setAttribute("value", `Air Quality: ${airQuality}`);
            })
            .catch((error) => {
                console.error("Error fetching data:", error);
            });
    }

    fetchData();
    setInterval(fetchData, 15000); // Update every 15 seconds
</script>
```

Fig. 7. Code to fetch data in ThingSpeak.

The flow of the application starts with authentication, for AR visualization, when capturing the image of the target object using the camera; the system scans the marker for recognition through comparison with an existing database. If the object or device is recognized, its information is retrieved from the *ThingSpeak* platform [13]. The energy data is displayed on the screen, overlapping the image of the recognized object [34]. There is also an alert functionality, users receive notifications when air quality values are abnormal.



(a) (b) (c)

Fig.8. (a) Authentication screen; (b) Homepage and menu; (c) AR visualization of data when scanning a marker whith camera

4. Results and Discussion

After the text edit has been completed, the paper is ready. In this section, we assess the performance of our WebAR application that visualizes real-time data from the DHT11 and MQ135 sensors. We conducted tests with 5 testers, measuring response time, load time, ease of use, Visual Appeal, and satisfaction of using the webAR application, the results are summarized in table 2.

Table 2. Metrics of the AR application using

Metric	Average Result
Load time	**0.7s**

Response time	1.2s
Ease of use	**4.8/5**
Visual appeal	4.5/5
Overall satisfaction	4.5/5

The application demonstrated an average response time of 1.2 seconds for updating the AR interface with new sensor data. The average load time was 0.7 seconds, showcasing satisfactory performance across different devices and browser environments. The ease of use, rated on a scale of 1 to 5, scored an average of 5, reflecting a user-friendly and simple useapplication. Visual Appeal was 4.5, and general satisfaction had an average of 4.5.

The application displayed a high level of accuracy in visualizing temperature (98%), humidity (97%), and air quality (96%) data, confirming its reliability in presenting the sensor data to users.

By evaluating the performance metrics with 5 testers, we can conclude that the developed WebAR application effectively visualizes real-time data from smart environment IoT sensors while providing a satisfactory user experience and accurate data representation.

Comparaison avec les 3 ou 4 articles :

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CONCLUSIONS

The aim of this article was to overview the application of AR in the context of a smart environment. Moreover, based on the literature review regarding the solutions for inexpensive energy monitoring, we proposed a webAR based IOT system for the measurement of temperature, humidity, and air quality in a smart environment. Augmented Reality and the Internet of Things are some of the newest technologies which are still undergoing developments in their applications in various fields. They have become a vital tool in the development of smart cities where they are applied for various functions. One of the primary usages of these technologies is the development of an energy-sensitive system that helps view, monitor, analyze, and act on various energy uses by different tools. The ability to track various energy objects and have instantaneous information on them will make it easy to monitor and therefore minimize energy usage. Finally, the applications of these technologies are just a scratch on the surface, and there is a need to carry on research on usage and improvements on the same for better results.

IMPROVEMENT AND FUTURE WORK

The purpose of this effort is to create a prototype that combines IoT and augmented reality technologies to create an intelligent environment that can be used in any location, including a smart house, a smart building, or even a smart city to regulate air quality. The system can be expanded as necessary with additional sensors and functionality.

Even if our work is giving a solution for hardware and ease of use challenges for AR applications, user privacy and data security in a smart environment remains a significant concern, especially as AR apps frequently entail the collection and processing of delicate visual data.

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