Smart toilet cleanliness detection system using IoT

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Abstract

Significant technological developments and improvements have emerged during the last decade, propelling us forward in this era of technological discovery. Regardless of the field of activity, this rapid evolution phenomenon has produced significant changes and improved human life, *acting as an incentive in developing solutions that improve the quality of life and well-being of all groups of people. Thus, this paper aims to present the implementation of a state-of-the-art system for detecting the cleanliness level of toilets. Used in the Toilet4Me2 project, this system addresses the adjacent problems concerning the cleanliness level of the toilets, such as different kinds of infections and bacteria. Health risks associated with this present a major concern, countries such as India being one of the most affected by this lack of toilet sanitation. Over the last years, the Indian government has made huge investments in the search for solutions, opening the door for implementing IoT technology in this aspect of our lives. Increased awareness has even spread to Europe. Many such projects focus on the quality of life and well-being of elderly and disadvantaged people, who are often overlooked in our society. Therefore the monitoring of a toilet's cleanliness represents an important factor in the ordinary lives of elderly and young people alike, results of its use showing an abrupt reduction in health risks and an increase in usage and accessibility. The scope of this project is to achieve these milestones and spread awareness of this silent problem in our society and all the risks related to it.*

Keywords: *Toilet cleanliness, IoT, health risks*.

1. Introduction

In day-to-day life, toilet use plays a very important factor, whether at home or outside and regardless of age. Playing such a quiet and important part became a basic need for most of the population, finding its place in every household. Unfortunately, not every aspect of it is treated as such. The cleanliness of toilets has become a recurring problem more and more people have to face every day, including its inherent risks. The toilet room is a vulnerable spot, closely related to our health and well-being. One's feeling of repulsion at the thought of sitting on an unclean toilet is the instinctive, natural response as it can lead to serious health risks [1]. These risks stem from the presence of different kinds of viruses and bacteria, such as Salmonella, that can be found in an unclean toilet bowl and from the spread of disease associated with its perpetual manner of use. Unfortunately, the SARS-CoV-2 Pandemic has turned toilet rooms into a hotspot for its transmission, aggravating the already serious problems related to their everyday use. [2]

India's struggle with toilet sanitation is becoming a subject of more importance as the associated inherent risks can no longer be ignored by the population. In [3], the authors present a visible problem in India, where diarrhea kills one child per minute. The cause is found in the improper sanitization of toilets, standing as a testament to the importance of this factor in people's lives from all around the world.

The Internet of Things (IoT) is a relatively new and evolving technique influencing the internet and communications technologies [4]. IoT enables individuals and things to be connected using any path, network, and service. Daily, modern people expect new devices and technologies to make their lives more manageable. Using smart devices, IoT is of great value in monitoring the level of cleanliness in toilet rooms. Smart homes, with smart speakers, toilets, refrigerators, ovens, and thermostats, offer assistance in our day-to-day lives using collecting and presenting information in an accessible way. Through enhancing adaptability and ease of access, IoT offers a platform that enables the improvement of certain aspects of life, including its application in toilet cleanliness.

The article will be presented as follows: Section II presents similar concepts of a smart toilet monitoring system used to enhance the quality of life of the experience, while in Section III, we propose and describe a smart monitoring system prototype that can be used in individual's homes or in public spaces. Section IV presents the devices and sensors used by the system, while section V focuses on the experiments carried out and their final results. Section V relates the results from the conducted experiments. Finally, Section VI completes the work and describes the new directions of future development.

2. Related work

As this technology evolves, people begin to find appliances in different areas of activity. In [5], the authors propose a toilet cleanliness monitoring system using IoT. This smart toilet uses intelligent sensors (MQ-137) that communicate with a microcontroller (NodeMCU). The gathered data is sent to be visualized in a dashboard made using ReactJS. A mobile application is also developed to allow the toilet's cleanliness status in real time. If the measured values go above a set threshold, an alarm signal is sent through the mobile application to the janitor, announcing that the toilet needs cleaning.

In [6] a variation of the first proposed system is presented using different components in implementing the IoT platform. Instead of using a MQ-137 sensor, this system utilizes an infrared sensor (HC-SR501), a flow meter (YF-S201) installed between the tap and the pipe and an ultrasonic sensor (HC-SR04) under the lid. All the sensors are interfaced with the Raspberry Pi (Model 3B+). As soon as a person enters the toilet room, the infrared sensor detects him, which sends a signal to the Raspberry Pi. It, in turn, activates the water flow meter, which starts to measure the amount of water flowing through the pipe. The water meter stops the measurement as soon as the person exits the room, the PIR (Passive infrared sensor) switching to idle due to the lack of movement. Suppose the amount of water is above or below a certain threshold. In that case, an SMS is sent to the respective janitor signalling a need for intervention, cleaning the toilet or tending to other issues.

The system proposed in [7] is, again, similar in architectural design, using a water conservation sensor fixed in the septic tank to measure the quantity of water used by the user, an RFID reader for detecting the sweeper's activity and a user detection system. Striving to solve India's long overdue problem with toilet sanitation, this implementation adds a Dirt Detection system by using an IR sensor and a smell sensing module using a Figaro Sensor. The dirt detection system works by comparing the image provided by the sensor with the default image sorted within (no presence of dirt). Similar to the other instances, the data gathered from the sensors is sent by a GSM message to the person in charge, with the help of a microcontroller.

A study [8] proposes a model for monitoring the indoor air quality monitoring system using various sensors (MQ135, MQ7, DHT11) to detect carbon dioxide, carbon monoxide, temperature, humidity and dust particles present in the environment. They are connected to a Raspberry Pi 3B+ micro-controller with an incorporated Bluetooth and Wi-Fi module. The gathered data is then displayed on the Thing Speak Website.

Another system is proposed [9] in which an 8-bit microcontroller is used for the sensor connection together with a modem connected to the Internet using the HTTP model. Sensor for carbon monoxide (CO), methane (CH4), ozone (O3) detection are used for air quality measurements, with a sampling period of 1 minute for each gas and programmed using the C programming language. In addition, the system is equipped with an antenna, an activation button and an 6600 mAh researchable battery. Everything is then visualized in an online dashboard (http://comcoman.com/qlog/).

3. Architecture

In the context of toilet cleanliness detection a reliable, scalable and easy to implement architecture was developed. This new prototype utilizes IoT technologies, thus requiring a stable Internet connection in order to achieve communication between devices. The prototype is fitted with a Wi-Fi module in order to facilitate communication with the MQTT Broker, which itself is connected to an open source database called InfluxDB. This database was chosen for its ability to easily integrate with Grafana, a web platform which allows data visualization through graphics, tables and diagrams.

Fig. 1. System architecture

Also, this visualization platform allows the use of formulas on the received data, making the interpretation easier. Another advantage consists in the ability to generate alerts through many different ways such as E-mail or Telegram.

The MQTT protocol [10] is used for its energy efficiency. It uses less energy than the HTTP protocol, which plays an important role in IoT applications with many user devices.

The general architecture of the toilet cleanliness system will be based on Big Data and will include communication protocols between server and platform (MQTT and HTTPS). The general “data” is translated into the numerical information of the sensors. The cleanliness detections sensors then turn physical parameters (such as the number of pollutants in a space) into electrical parameters (such as electric potential), which are shown either analogical or digital depending on the sensors.

The data is then processed and improved by keeping in mind the specific rules of the sensors and the specific algorithms. Next, it is sent through specific protocols in the storage space (InfluxDB) in order to be accessed for its visualization in the dashboard (Grafana).

4. Used devices

The air quality monitoring equipment in the toilet consists of a hardware unit consisting of a Raspberry Pi 3B+ development board, 3 gas sensors (MQ137, MQ136 and MQ135) and a sensor for temperature and humidity detection, which are integrated into the system via the already mentioned MQTT communication. Monitored parameters include:

- Ammonia (NH3)

The range of this sensor is between 0 and 500 ppm. The sensor used is dedicated to the detection of ammonia variation in the breathing air. It operates at a supply voltage of 5V and the estimated service life is more than 2 years.

- Hydrogen sulphide (H2S)

The range of this sensor is between 0 and 200 ppm. The sensor used is dedicated to detecting the variation of hydrogen sulphide in breathing air. It operates at a supply voltage of 5V and the estimated service life is more than 2 years.

- Temperature (TC)

The temperature sensor works between -40 and 85 ºC with an accuracy of ±1 ºC. It detects the temperature of the breathing air in the toilet room.

- Humidity (HUM)

The humidity sensor takes values between 0 and 100%, with an accuracy of ±3%. It operates at a supply voltage of 3,3V and the estimated service life is more than 1 years.

As well as less important parameters related to the air quality such as: Sulphur (S), Benzene (C6H6), CO2 and smoke (yellow)

Fig. 2. Used sensors

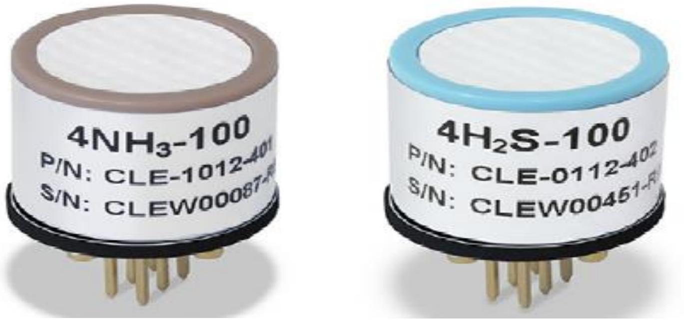

Fig. 3. Libelium sensors
Source: https://www.libelium.com/

The main difference between MQ sensors and Libelium sensors is the sensitivity with which they detect the presence of the measured gases. Libelium sensors are much more rigid when it comes to small amounts of gas. Because of this, their use in a toilet is not efficient. Another disadvantage of these sensors is the much higher price compared to the solution given by MQ sensors.

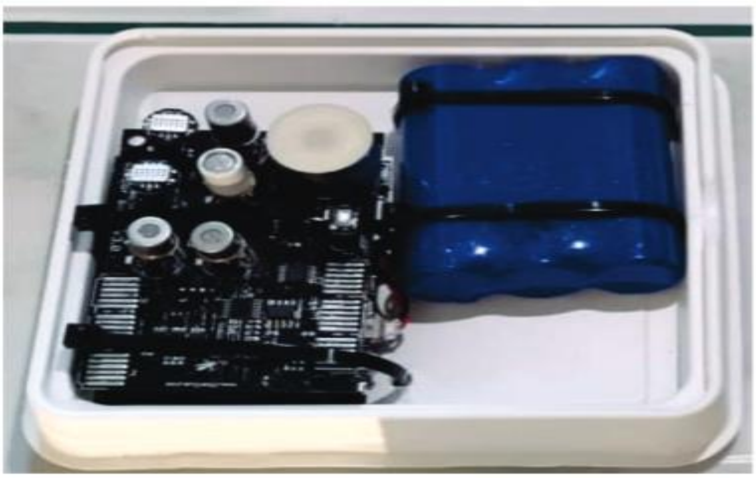

Fig. 4. Monitoring station

5. Experiments

The system was tested in the toilet room from the BEIA offices. The sensors monitored the toilet during its use on an average working day. The graphic below presents the recorded values of each respective measured parameter.

MQ135 - Ammonia (NH3), Sulphur (S), Benzene (C6H6), CO2 and smoke (yellow)

MQ136 - H2S (blue)

MQ137 - NH3 (orange)

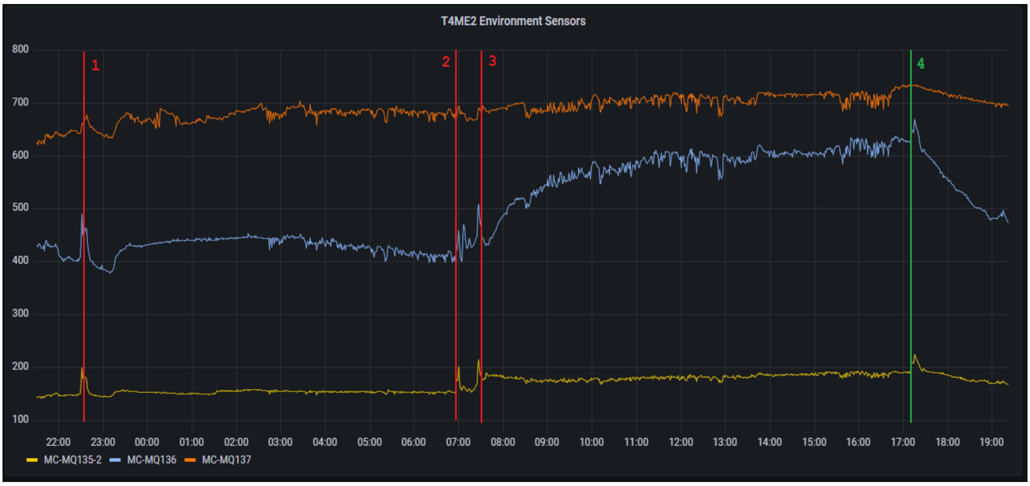

Fig. 5. Experimental results

The first event (1) translates in the use of the toilet by a person. The toilet bowl was cleaned immediately and it can be observed that the values recorded adhere to the norm. The second (2) and third event (3) conveys the use of the toilet by a second and a third person respectively. The toilet bowl wasn't cleaned afterwards and a rise in the levels of Ammonia and Hydrogen sulphide is immediately noticeable. This informs us that the toilet is unclean and needs immediate rectification action. The fourth event (4) consists of the second cleaning of the toilet. It can be easily seen that the levels of NH3 and H2S drop significantly to their original value. This experiment is meant to attest the hazardous nature of an unclean toilet and the importance and necessity of regular cleaning and maintenance. Further experiments will be conducted in order to achieve better and clearer results.

6. Conclusions

Toilet cleanliness has become a large problem for countries like India, where a lot of resources and time is spent on tackling the sanitization of toilet rooms. This solution presents a low-cost, easy and reliable system in hopes of reducing the risks associated with the dirtiness of the toilet room and improving the overall experience. As for future research directions, the integration in a smart toilet system is followed, as well as the addition and implementation of an air quality monitoring system.

Acknowledgements

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