

LOW-COST TEMPERATURE AND HUMIDITY MONITORING SYSTEM IN HOSPITAL AMBIENCE

SISTEMA DE BAIXO CUSTO PARA MONITORAMENTO DE TEMPERATURA E UMIDADE EM AMBIENTES HOSPITALARES

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Abstract: A temperature and humidity monitoring system is to check and show the climatic variances of the hospital’s ambience continuously as well as communicate with the professional responsible for obtaining this type of information. The study proposes a low-cost system that read both temperature and humidity through a capacitive sensor with an accuracy of ±2% relative humidity (max ±5%) and temperature precision < ±0.5°C Celsius for monitoring hospital departments such as Central Sterile Supply Department, Transfusion Agency and Surgical Center. The microcontroller receives the data from the sensor and sends it to the internet communication module, which shows the information to the user. The method used nowadays is done by manually populating tables which offer the risk of human error or data loss. The proposed system also consists of a web platform and an Android application that shows the real-time variables and generates reports of readings and alerts to unwanted variations. It could be able to modernize the process of monitoring the hospital’s departments using the Internet of Things (IoT).

Keywords: Temperature. Moisture. Hospital environment. Internet of things (IoT). Microcontrollers.

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Resumo: Um sistema para monitoramento de temperatura e umidade deve avaliar e apresentar a variação de climática em ambientes hospitalares continuamente bem como se comunicar com o profissional responsável por obter esse tipo de informação. Este estudo propõe um sistema de baixo custo que é capaz de obter dados de temperatura e umidade através de um sensor capacitivo com a acurácia de ±2% de umidade relativa (máx. ±5%) e precisão de temperatura < ±5º Celcius para monitoramento de áreas de hospitais como a Central de Materiais Esterilizáveis, Agência Transfusional e Centros Cirúrgicos. O microcontrolador obtém os dados do sensor e os envia para o módulo de comunicação por internet, o qual mostra as informações para o usuário. O método utilizado atualmente é realizado com a alimentação manual de tabelas, o que oferece riscos de erro humano ou perda de dados. O sistema proposto também é responsável por leituras e alertas para variações indesejáveis. Seria possível modernizar o processo de monitoramento das áreas do hospital com a utilização de Internet das Coisas (IdC).

Palavras-chave: Temperatura. Umidade. Ambiente hospitalar. Internet das Coisas (IdC). Microcontroladores.
1 INTRODUCTION

The hospital areas are categorized according to their risk degrees, after the National Health Surveillance Agency (ANVISA) standards, such as: critical areas, where invasive rules are performed, and are intended for patients with increased susceptibility to infectious agents, for instance, the Central Sterile Supply Department (CSSD); semi-critical areas, where there is less infectious agents’ transmission risk, like pharmacies and nurseries; and non-critical areas, whereupon there is no disease transmission risk, e.g. the Diagnostic Imaging Department (ANVISA, 2002).

The rooms where the surgical processes occur, because they are critical environments, need attention to air quality and climatic factors, therefore avoiding the risk of developing infections related to the hospital environment. In addition, the ambient temperature is considered a quality factor in healthcare, once it influences employee’s behavior and the recovery of the patient, promoting greater comfort during their passage through the Health Care Establishment (HCE) (VERDE et al., 2015).

Technologies used in the diagnostic imaging department need controlled temperature and humidity. The recommended values should be between 21°C and 24°C and humidity between 40% and 60% (ABNT, 2005), thus in compliance with these recommendations may avoid adverse events related to the integrity of the device and the safety of employees and patients (GHIZDOVÁT et al., 2015).

For the CSSD, which is responsible for the processing of health products, the temperature is defined between 20°C and 24°C, and humidity between 40 and 60% (ANVISA, 2002). This standard is related to work comfort and biosafety, due to the increasing complexity of procedures performed within hospital institutions, and the reliability that the CSSD must present. After all, the materials sterilized used in medical procedures happen in this sector (RAWLANCE et al., 2015).

In the hospital pharmacy, the specific temperature for each product should be obeyed, and these values should be monitored daily (ANVISA, 2009). Despite the norms that regulate for the hospital departments about the climatic measurement, the HCE, for the most part, does not have a rigorous monitoring of the temperature and humidity, using manual annotations in tables and maps. This practice does not guarantee its reliability due to the lack of frequency of records, uncertainty in measurements, human error and the possible loss of the manually filled form. In this way, it is possible that the monitoring is through autonomous systems that store and make available the data guaranteeing the quality of service (GONZALEZ-PALACIO et al., 2018). Applications and web pages can interface to data collected by microcontroller...
board platform; thereby systems designed for healthcare applications are developed based on different perspectives such as the application, the sensors used for information detection, data management and security (KARTHI; RAJENDRAN; MATHIARASAN, 2017). Thus, the microcontroller-web application system is categorized as Internet of Things (IoT), ever since it enables an interface between the user, the machine and the object, providing the requested information immediately (DEWON; HWAMIN, 2018).

The present study proposes a temperature and humidity monitoring system can alert and making available information from the readings performed in hospital ambience. With the prototype, it is also possible to make a future conferring feasible through reports that can be accessed and shared in an integral or partial way. Therewithal, it may mitigate the errors and avoids the data losses occurrence or human failure possible to the monitoring of these parameters. The test with the prototype was performed in a private hospital in the city where the research was made, composed of three hundred beds with specialties in the areas of maternity, orthopedic, plastic surgery and surgical clinic.

2 MATERIALS AND METHODS

2.1 Research Description

The experimental and quantitative research was performed in a private hospital of a Brazilian city, composed of three hundred beds with specialties in the areas of maternity, orthopedic, plastic surgery and surgical clinic. The hospital has departments that can be monitored such as the CSSD preparation room, the pharmacy and the blood bank. In this way, the system was designed to attend the monitoring required by these sectors.

2.2 Prototype Design

The project was built in two stages, the first one contemplating the prototype development: hardware and software, and the second included the data collection. For the hardware development was used the Arduino, which is an open platform of electronic prototyping with a microcontroller, whose simple interface allows information acquisition and device controls (DIGARSE; PATIL, 2017). The board enables the use of sensors and actuators necessary to collect of information such as temperature and humidity of the hospital ambience and provides the professional with the obtained data (ESPINOZA-RUIZ et al., 2015). In addition, the sensor AM2302 DHT22 was incorporated aiming to read both, humidity and temperature, values. The sensor’s technical specification (MINIPA, 2012) can be observed in Table 1. Thereby, the sensor is connected to the Arduino - Uno microcontroller directly besides the W5100 Ethernet Shield.
allows a connection to the local internet through the IP configuration.

| Table 1: AM2302 DHT22 technical specification |
|-----------------------------------------------|
| Model | AM2302 DHT22                              |
| Power supply | 3.3-6V DC                              |
| Operating range | Humidity 0-100%RH; temperature -40~80°Celsius |
| Accuracy | Humidity ± 2%RH (Max ±5% RH); temperature ≤±0.5°Celsius |
| Resolution or sensitivity | Humidity 0.1%RH; temperature 0.1°Celsius |

The software development required the Arduino programming code, a smartphone application, Laptop and an Android 7.0 smartphone. The Arduino IDE itself and C / C ++ and HTML language were used to create the code that has the sensor routines, server-client connection and the web page.

Web applications are rapidly becoming an attractive and cost-efficient way of developing mobile applications. In this project, the application was designed and written using JavaScript, as the web technologies trending’s on mobile browsers implement standards like HTML 5, CSS 3 and JavaScript (MIC HI E L; J A N; V I N C E N T, 2016). The application has a function called “file”, used to create a new file in the internal storage of the mobile device through Google Fusion Tables. From this, the file was defined as “.csv” (Comma-separated values) as its name and the extension, which were determined to aim at greater compatibility with applications and spreadsheets management software. Using the inherited functions of the “file” feature, it was possible to create and feed the database as the temperature and humidity were read out by the above-mentioned sensor. This database can be presented to the user in the report screen or shared via the “share” button.

2.3 Prototype Test

The second stage is characterized by collect of data using the prototype in the hospital’s department chosen for observing its operation and performance. Thus, the accuracy was analyzed exposing the prototype to the temperature and humidity of the CSSD’s preparation room. Subsequently, the values obtained by the prototype with those of the thermo hygrometer of the hospital was compared. The device used was the Minipa Wireless Interface Thermometer MTH-1362W 14 with an accuracy of ±0.5°C for the temperature range +10°C ~ +45°C and for humidity the accuracy is ±2.5% at 25°C for a range of humidity between 10% ~ 90%. The CSSD was chosen for the test because it is an environment that deals directly with the variations
of humidity and temperature due to the nature of the service provided.

3 RESULTS

The system consists of the input, control, output and power supply units, whose block diagram is presented by Fig. 1. The temperature and humidity sensor (DHT22) is positioned in the ambience that will be monitored so that the weather conditions are read. The informations acquired by the sensor, the input unit, are fed to the controller unit. This unit is represented by the Arduino Uno, which receives the ambient temperature and humidity values continuously from the input unit. The microcontroller is programmed using the Arduino IDE. Thus, the programming developed for the Arduino will compare the input value with the default value and, through communication established with the internet by the Ethernet Shield W5100, it is sent to the output unit a conditional (normal or abnormal), for the values of temperature and humidity that is not according to the previously established parameter. The output unit consists of Android Mobile Application and a Web Platform so that the values of the variation of the temperature and humidity are shown in real-time, as well as the climatic conditions that leave the parameters. Both, Android Mobile Application and the Web Platform, allows the user receives the data for the monitored sector and, in case of abnormal conditions, Web Platform will display an alert message on the screen and Android Application will alert the user through a push notification.

Figure 1: Block Diagram of a Smart Health Environment System.

The Fig. 3 shows the components used to develop the hardware, (1) Arduino Uno, (2)
Shield Ethernet W5100, and (3) the DHT22 sensor.

Figure 2: Components used to develop the hardware.

The proposed technique for sending data from the monitored environment to the user is depicted in the flowchart shown by Fig. 3. The temperature and humidity are monitored and when there are abnormal changes the user is alerted. The data is continuously saved over time.
The Web page has in its interface: the sector where the reading is being carried out and the values of temperature and humidity in real time. By means of a conditional code structure, developed in the Arduino IDE, it is possible to create an alert, which displayed on the screen, in text form, for variations in temperature and humidity that exceed the range of recommended values.

The application has an interface similar to the web page and has a button that directs to the report screen, in which the data collected throughout the day is displayed. The Fig.4 shows...
the application interface, which was designed in Portuguese, and its functionality as well.

The application for temperature and humidity monitoring prototype was developed in a three-screen architecture: main screen, shown in Fig. 4 A, containing the buttons (1) that lead to the monitored environment, shown in Fig. 4 B; in this screen, to check the sector, in (2) it is possible to determine the time interval in which the reading information of the sensor will occur, in addition in (3) shows the temperature and humidity reading information of the selected environment in the main screen; the return button to the previous screen in (4) and the button that directs to the report screen in (5); the report screen, shown in Fig. 4 C, shows the previous monitoring tool in (6), the readings record in (7), the button “return” to the previous screen in (8) and the data export button in the spreadsheet format in (9).

Figure 4: Application main screen (A), Environment monitoring screen (B), Report and Sharing screen (C).

The code was programmed to enable the variable declarations and the using of timer function to update and synchronize web page data with the Application directly. With a function that send a notification in n seconds with the corresponding title and text it was possible to program push notifications from situations in which the values read by the sensor are different from the intervals defined for temperature and humidity. A delay has also been implemented in the code for the notification, so that the user is not notified if there is only a momentary and insignificant variation of the parameters in the environment.
With the “file” function of the platform it was also possible to make the creating possibility and updating a file defined with the extension “.csv” from a timer and in situations of irregularities in the values read by the sensor.

The temperature and humidity reading of the CSSD preparation room was possible by setting the prototype on the local internet using the RJ45 network cable and the hospital router so that the prototype was connected to. Thus, the application got the information just as the Web page and notified when reading abnormal values of humidity, considered ideal between 40% and 60%. The temperature remained adequate in the test samples and there was no warning. The reading values are shown in Table 2.

| DHT22 Temp (°C) | Measurer Temp (°C) | Variation Temp (°C) | DHT22 Hum (%) | Measurer Hum (%) | Variation Hum (%) |
|-----------------|--------------------|---------------------|---------------|-----------------|------------------|
| 22.00           | 21.65              | 0.35                | 63.60         | 64.81           | 1.21             |
| 22.00           | 21.65              | 0.35                | 63.60         | 64.81           | 1.21             |
| 22.00           | 21.65              | 0.35                | 63.90         | 64.54           | 0.64             |
| 22.00           | 21.65              | 0.35                | 64.30         | 64.88           | 0.58             |
| 22.00           | 21.65              | 0.35                | 64.30         | 64.88           | 0.58             |
| 22.00           | 21.65              | 0.35                | 64.30         | 64.88           | 0.58             |
| 22.00           | 21.65              | 0.35                | 64.30         | 64.88           | 0.58             |
| 22.00           | 21.65              | 0.35                | 64.30         | 64.88           | 0.58             |

In this table the values of temperature and humidity can be visualized according to the reading realized by the sensor DHT22 and the measurer (thermo hygrometer). The readings obtained small bands of variation in relation to the prototype and the thermo hygrometer, that varied in 0.35°C for temperature and 0.71% for humidity. These limits are tolerable since the accuracy of the Minipa thermometer is ± 0.5°C for the temperature range + 10°C ∼ + 45°C and for humidity the accuracy is ± 2.5% at 25°C for a range of humidity between 10% ∼ 90% (MINIPA, 2012).

Due to the importance to check parameters such as humidity and temperature in HCE’s vulnerable ambience and based on the existing high cost and low access technology, it was possible to develop a low-cost open-source hardware and software. The prototype was estimated, through market research, with a price of 25% under the value of commercialized...
devices with similar functions and accuracy. Thus, the developed prototype could be considered as a possible solution for adverse events caused by both the lack and the failure to check climatic factors in HCE.

ANVISA recommends, through Public Consultation no. 343, dated May 11th, 2017 (ANVISA, 2017), the usage of computerized supervision systems and, in the case of temperature, has visual and/or audible alarms to signal unconformities with the stipulated acceptance range. The solution becomes possible and coherent due to use a device developed through independent hardware and open-source software. this may bring, as a characteristic, the capacity to insert temperature and humidity sensors’, indicators, and alarms what may make this system be in accordance with regulatory requirements.

The present study aimed at designing a system composed by software and hardware for real-time measurement of parameters using the Arduino Uno, Shield Ethernet application developed to show the variables read by the sensor and store it on a database. The device was used for testing in the CSSD’s preparation room and, as shown in Table 2, presented some momentary variations which, considering the ideal local humidity between 40% and 60% was irregular. At the same moment, the Android mobile application accused the abnormal value of the humidity and notified to alert about the ambience reading. The recording of these measurements can be used as a tool for decision making to avoid the occurrence of adverse events. Through the data obtained, during the reading performed in the hospital departments, it was possible to observe the accuracy of the prototype in relation to the Minipa’s thermo hygrometer. The result pointed to a reliable reading since the variation is considered tolerable by the norms presented in this research.

4 CONCLUSIONS

It was concluded that the implantation of a temperature and humidity monitoring system in healthcare areas can provide a safer and reliable services. In addition to hospital ambience, this system can be applied in other areas, such as the pharmaceutical, food and agro-industry. The benefits related to the aim of this subject includes the prevention of equipment failures that depend on temperature monitoring, reduction of drug losses that must be maintained under temperature and humidity stipulated by the manufacturer, moreover a safe storage of food according to the ambience. Besides that, the low-cost prototype is estimated in a price 25% under the price of commercialized devices with similar functions and accuracy.

For future research, it is suggested to increase the number of temperature and humidity monitoring modules in others hospital’s department. Furthermore, different sensors can be
implemented to the system to expand the monitored variables’ number, such as the particle pollution and air quality. In this way, it may aid the professionals involved on the regulations’ compliance required of the hospital.

Finally, although monitoring of the parameters can be done manually, imprecision due to possible human errors in the recording of information, periodicity and possible deletions of the document may compromise the performance of activities within a HCE. Such consequences could be circumvented through a low-cost monitoring system that fulfill the professionals’ requirement.

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