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APLICATION OF THE INTERNET OF THINGS (IoT) CONCEPT ON THE INTELIGENT CONTROL OF FRESH AIR IN AN APHITHEATER

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RESUMO

O presente trabalho aplica a Internet das Coisas (IoT) no contexto de sistemas de ar condicionado, mais especificamente em uma aplicação de controle da qualidade ar interior. Inicialmente projetou-se um controle para vazão de ar exterior de renovação insuflado no ambiente, utilizando as variáveis concentração de CO_2, número de ocupantes no ambiente, atividade metabólica dos ocupantes, taxas de infiltração e exfiltração de ar, foi então efetuado um cálculo mais preciso da vazão de ar de renovação requerida. O sistema implementado inclui sensores de CO_2, pressão atmosférica, frequência cardíaca, além de velocidade e direção do vento, todos conectados à microcontroladores que enviam os dados coletados à plataforma na nuvem IBM Watson. Desta forma obtém-se um controle mais eficiente e diminuem-se os gastos energéticos, além de garantir-se a qualidade do ar no interior. As simulações realizadas por meio do programa MatLab demonstraram que a solução implementada diminui os gastos energéticos da ordem de 14% do consumo energético referente ao tratamento do ar externo a ser insuflado no ambiente.

Palavras-chave: IoT. HVAC. DOAS. QAI. Internet das coisas.

ABSTRACT

This work applies the Internet of Things (IoT) in the context of air conditioning systems, more specifically to control an indoor air quality application. Initially, it was designed a control for the external airflow of renewal inflated in the environment, using the variables CO_2 concentration, number of occupants in the environment, metabolic activity of the occupants, rates of infiltration and exfiltration of air, a more accurate calculation was carried out of the required renewal airflow. The system implemented includes CO_2 sensors, atmospheric pressure, heart rate as well as wind speed and direction, all connected to microcontrollers that send the data collected to the platform in the IBM Watson cloud. In this way a more efficient control is obtained and the energy expenses are reduced, besides guaranteeing the quality of the air in the interior. The simulations carried out through the MatLab program demonstrated that the implemented solution reduces energy expenditure by 14% of the energy consumption related to the treatment of external air to be blown into the environment.

Keywords: IoT. HVAC. DOAS. IAQ. Internet of things.

1 INTRODUÇÃO

Air conditioning systems represents an expressive amount of energy consumption of a building, reaching 60% according IEA. In this context, the control of ventilation is an important point for the energy saving strategy. Demand Controlled Ventilation (DCV) has been used usually with CO_2 sensors that estimates the occupancy of the ambient and insufflates the amount of renovation air according to ABNT standard NBR 16401, or ASHRAE standard 62.1.

In that configuration, a sensor measure the concentration of carbon dioxide in the ambient and estimates the number of people inside, allowing a gradual control of the air renovation rate based on ASHRAE standards. However CO_2 sensors require calibration for the correct mensuration and there are different measurement principles and methods that induce large differences in the value obtained (Mysen et all, 2014). In addition, when sensors detect sufficient amounts of CO_2 to trigger the required ventilation, occupants may already be feeling uncomfortable.

Currently the trend for DCV systems is direct counting of occupants, which allows maximum system efficiency, in contrast to common inference systems, which estimate the occupancy in the ambient. There are several approaches, as the use of monitoring cameras and the WiFi network. The challenge for implementing these techniques is to balance cost, accuracy, intrusion level and privacy, which are all interrelated

In line with the recent trend, the implementation of the Internet of Things (IoT) paradigm in air conditioning systems presents considerable potential in improving energy efficiency, allowing a more precise control of the outputs of a system through the analysis of variables obtained and processed remotely.

The central objective of the present work is the implementation of an IoT-based solution with an occupancy monitoring for a more precise control of the air renovation flow rate supplied to a classroom, in accordance with national legislation and based on the ABNT, NBR 16401-2008. Using access points and smartphones with WiFi connection, is counted the number of occupants of the ambient.

2. Methodology

This paper focuses Dedicated Outdoor Air Systems (DOAS) on single zone systems. The fresh airflow rate was determined based in the dilution equation, Eq. (1). Was attempted to hold the increase of CO_2 concentration by letting the concentration rate near to zero. To avoid large values of fresh air flow rate was established a set point of 800 ppm of CO_2 to turn on the fans.

VOL(dC_in)/dt = V_inf.C_out - V_exf.C_in + V_ins.C_out - V_ret.C_in + G (1)

In the proposed model, CO_2 generation was determined by the occupancy and heart frequency, as shown in Eq. (2).

VCO_2 = (8,845.10-7 bpm3 - 0,00012 bpm2 + 0,0138 bpm - 0,288).0,83 (2)

The infiltration and exfiltration is determined by the pressure differential as shown in Eq. (3)

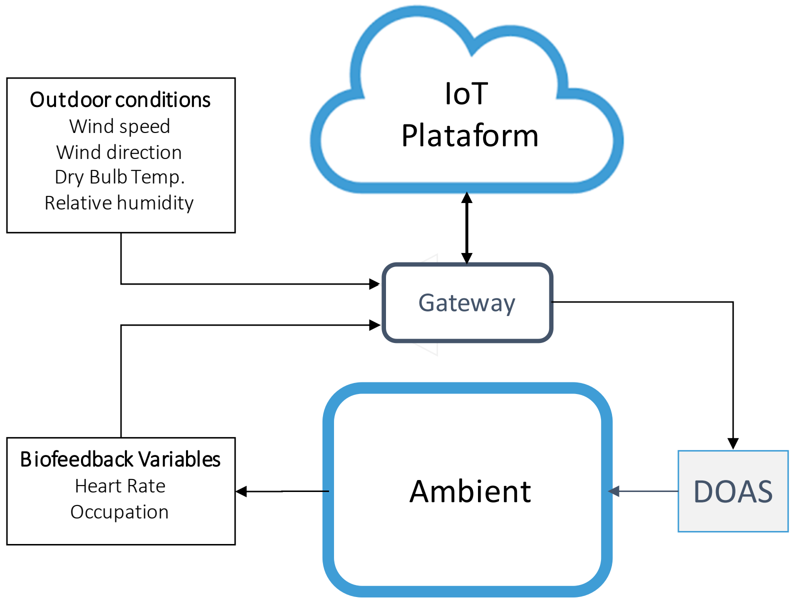
ΔP = P_atm ext + (C_p .ρ.U ^{2})/2 - P_atm int (3)

All the sensors were tested and connect to the cloud, where the algorithm for the air quality was implemented. The results about air quality and energy consumption was obtained by computational simulation.

3. IMPLEMENTATION

The proposed IoT solution consists in the control of the renovation air using several data from sensors and sent to the cloud using the internet of things paradigm, as shown in Fig. 1. Information processing, which will indicate fresh air, occur in the cloud on a commercial available platform. It is important to say that the solution presented is low cost and uses commercial components with accessible value.

Figure 1. Scheme of the IoT solution proposed.



The implementation local is a classroom of Department of Mechanical Engineering, located at University of Brasília, UnB, which has a quarter of a circle pattern with a radius of 13 meters. The height is approximately 3 meters. The space is classified as an ambient of studies according to the norm ABNT 16401-3. The classroom has six split air conditioners and has a dedicated air duct that is not been used, in addition to six grilles where there is infiltration or exfiltration of air. The place has infrastructure for implementation of the IoT solution, having WiFi network and electrical power plugs.

3.1 Cloud plataform

The IBM Cloud platform (or Bluemix) was closed in a trial version due to the extensive documentation available for use of the platform and because the features provided are sufficient for project development, such as the capability to register multiple devices, the capability to process data and send commands to actuators. As this platform is based on open source Cloud Foundry software, any change of platform does not cause changes in the developed application, which can be developed in any language. The model used was the platform as a service (PaaS), using computational and storage resources of the platform and developing our own solution.

3.2 Devices

Devices are sensors and actuators. As they are simple and low cost equipments, they are connected to microcontrollers to allow them sending data to internet. Microcontrollers are programmed in C ++ language and have libraries available for various features.

Heart rate was measured through a specific infrared sensor (Pulse Sensor) positioned at the fingertip of one of the occupants. The code for heart rate detection is provided by the sensor manufacturer itself and uses the "getBeatsPerMinute" function from the "PulseSensorPlayground" library to convert the analog signals to heart rate value. The heart rate (bpm) was used to estimate de production of CO_2 (VCO_2).

For the measurement of temperature and internal atmospheric pressure, the sensor BMP-180 was used. This sensor has an internal circuit and I2C serial interface (inter-integrate circuit), so digital signals are obtained. For CO_2 measurement was adopted a non-dispersive infrared sensor which measures the amount of CO_2 by calculating the absorption of emitted infrared waves.

The infiltration of external air was determined with an anemometer and a wind vane.

The occupation was measured using ARP scan, that count the number of IPs address been use in some network. A Raspberry Pi was used to run the code of ARP scan and to do function of gateway, sending the data collected to the IBM cloud.

A microcontroller board was used as actuator, receiving commands from the cloud and controlling a frequency inverter.

4. RESULTS AND DISCUSSIONS

To validate the IoT application proposed, simulations at MatLab were made, using the dilution equation and historical data from climate conditions of Brasilia. A restriction was imposed for the range of actuation of the DOAS fan, because it can operate according it performance curve.

The control of ventilation’s flow rate was set to a maximum of 0,8 m3/s and a start point at 800 ppm of CO_2 concentration. The results of numerical simulations showed a reduction on the energy consumption about 14 % of the proposed solution in comparison to a fixed value of ventilation based on ABNT standard.

Occupancy monitoring is one of the major challenges of the proposed solution.

Scanning based on the ARP protocol has the advantage of having very simple implementation and does not require the use of any additional hardware or software, but with the migration of IPv4 to IPv6 addressing, this scanning method won't be effective.

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