Indoor Air Quality Improvement

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1 Motivation

Good indoor air quality is a vital part and has great importance for human health. If quality of indoor air is not good, it can contribute to the development of chronic respiratory diseases such as asthma, heart disease, and lung cancer. Poor air quality is extremely difficult for humans to detect through sight and smell alone and existing sensing equipment is designed to be used by and provide data for scientists rather than everyday citizens. We typically spend 90 percent of our time indoors eating, sleeping, working, cooking, and spending time with our loved ones. Yet, some of our activities degrade the environmental quality of these spaces. For example, cooking, lighting a fireplace emits carbon dioxide particles and dust into the air. Clean air can prevent many environmental health hazards such as asthma. Although CO2 is considered as nontoxic, higher levels can cause health problems to the occupants such as dizziness, headaches, lower efficiency and aggravated problems under long term exposure.

Thus, there is a need of proper ventilation system that can create a healthier environment by allowing clean air to circulate from other rooms. As sometimes the air in the other rooms may not be of good quality. In such case, we can vent the outside air at the same time taking into consideration the temperature of the room, but without it, the air in a building can actually be worse than the air outside. The design of such ventilation system should be energy efficient. Energy management is one of the important factors that must be considered while designing efficient ventilation system. Using such energy efficient system, we can reduce the cost required to achieve ideal conditions in the room. For reducing the power consumption we have to design a system based on occupancy patterns and use historical data prediction which will result in an energy efficient system.

2 Related Work

Wireless Sensor Networks (WSNs) have been gaining in popularity as a promising alternative for monitoring the physical conditions of an environment. Researchers have conducted extensive research in WSNs, including localization [1], data forwarding [2]-[19], energy optimization [20]-[24], security [25]-[31], and utilizing sensor networks for applications such as smart grids [32]-[37] and smart health [38], [39]. Most related work relevant to our proposed method can be divided into the following categories: localization, energy optimization, and sensing air quality.

1) Localization: Our proposed work relies on historical location data of users within their home to predict usage patterns. So, it is important that state of the art techniques are being implemented to accurately identify a user’s location. Hoble [40] proposes a method that measures Channel State Information (CSI) by characterizing the multipath and Doppler effect of WiFi signals to predict the location, movement, and identity of humans. Social-Loc [41] and 3D-ODIL [42] improve indoor localization by exploiting encounter and non-encounter events to help existing localization systems and presenting a 3-dimensional on demand localization system, respectively.

2) Energy Optimization: Due to the low power nature of sensor nodes, researchers have proposed several solutions to reduce power consumption in WSNs. eShare [43] focuses on improving the efficiency of energy sharing by developing energy charging and discharging mechanisms for energy routers. DEOS [44] presents a dynamic energy-oriented scheduling method which allocates tasks based on the amount of energy available. The authors of [45] propose leakage-aware feedback control techniques to harvest unused energy that would have otherwise been wasted.

3) Sensing Air Quality: Sedentary indoor lifestyles are becoming more and more common. So, researchers have proposed several indoor air quality sensing/control techniques to reduce the risk of health problems associated with poor air quality. inAir [46] introduces a method for measuring air quality by analyzing tiny hazardous airborne particles. The authors of [47] designed a dynamic indoor quality control algorithm which monitors CO2 concentration to adjust ventilation rates. Beyond CO2 [48] considers various types of organic compounds and determines that air quality can be measured based on temperature and odor.

Unlike previous work this paper introduces an air quality control mechanism that reduces power consumption by utilizing historical usage patterns and human localization.
3 Design

In this project we have taken following approach to tackle the problem and to achieve the specified goal. For this project we have designed an efficient algorithm and simulator for air ventilation system using occupancy sensors. Also designed and implemented an algorithm for good quality air circulation which is taken from outside the house. The simulator that we have developed simulates the entire air quality control system and shows entire system activities graphically. System gathers historical occupancy data and shows it on web application using graphs. Also developed and implemented future occupancy detection algorithm in the simulator which uses historical data to predict future occupancy in the specified room. Following are the major design approaches that are implemented into the proposed system.

3.1 Forced-air system

In this project primary consideration is that the houses consist of a forced-air system. This uses air as its heat transfer medium. These systems rely on ductwork, vents, and plenums as means of air distribution, separate from the actual heating and air conditioning systems. The return plenum carries the air from several large return grills (vents) to a central air handler for re-heating. The supply plenum directs air from the central unit to the rooms which the system is designed to heat. Regardless of type, all air handlers consist of an air filter, blower, heat exchanger/element/coil, and various controls. Like any other kind of central heating system, thermostats are used to control forced air heating systems.

3.2 Occupancy based air circulation

In this system we not only provide good air quality but also consider the energy consumption for heating/cooling the home. In the proposed system, air circulation takes place only when occupancy is detected in the room. We also tried to avoid the false positives that are caused by the occupancy sensors. We have added special delay after occupancy is detected in the room. If even after the specified time delay room is still occupied then we start the system. As the air circulation in this system is two way air transfers, which helps to reduce pressure in air ducts and improve efficiency of air ventilation and speed up the air quality improvement process.

3.3 Future Occupancy Prediction

For predicting the future occupancy in the specific room we have developed and implemented the special algorithm in our simulator. Algorithm is described in detail as follows. In this approach we collect data for one month day wise. Algorithm divide each day into 15 minutes time slots so for each day there will be 24x4 = 96 time slots available. We mark the time slot as occupied if the given time slot is occupied for more than or equal to 10 minutes. Then next step is to find out if for the required day what the occupancy was in the room for last 4 days i.e. for next Monday we will consider last four Mondays in the month. If the room was occupied for the last four Mondays for specific time slot then we will consider the time slot of next Monday as the occupied and condition the air in that room at that specific time slot. We used logical AND operation to calculate occupancy. Because we want to be so sure that the time slot will be occupied and there will be no wastage of energy to condition the air in that room.

3.4 Taking outside air

For this system we have developed an algorithm that takes the air from the outside if the outside temperature is in the specified range, because most of the time outside air is of good quality. We used special weather forecast API to get the outside temperature so we dont need extra temperature sensor. In a situation where the air inside all the room is bad and specific rooms air is need to be conditioned then even if the outside temperature is cold/hot we need to take air from outside. In this situation we will take air form outside and circulate that air through the air heating/cooling system and try to bring down the temperature or increase temperature of the air to comfort level.
Month = May

1 + 1 + 1 + 1 = 1 (Logical AND Operation)
So Next Monday from 5:15PM to 5:30PM Occupied

3.5 Air quality control simulator

We developed a web application/simulator for air ventilation algorithm, CO2 level measurement, temperature measurement and to display all the information through the graphs. We are preventing the short cycling of the HVAC by not turning it on and off faster than its specified rate. This simulator considers increase in CO2 due to activities other than breathing. Also this simulator simulates the future occupancy prediction algorithm as described earlier. This simulator helped us understand the overall system.

We used following graphs to get drop in CO2 levels for our simulation.

3.6 Consider various activities

Apart from normal breathing humans do other activities in the house. These activate affects the drop in the CO2 level in the house. So we have made provision in our simulator to simulate the other activities. What our simulator does is it measures the drop in the CO2 level periodically and according to that drop in CO2 level it will start the overall system to condition the air.

3.7 Preconditioning of House

Usually what general survey shows that people reach home from work around the 5 to 6 o’clock in the evening ev-
every day except Saturday and Sunday. So what we proposed to do in our system is to precondition the entire house in that time span. This technique gives the good air when it is mostly needed.

4 Evaluation

Energy consumption of our model depends on the occupancy, system starts improving the air only when occupant is present in the room so the energy consumption is directly proportional to the occupancy.

So we have evaluated our system for the energy consumption depending on the occupancy.

Below graph [Figure 5] shows the energy consumption we calculated using our simulator.

5 Issues Faced

5.1 Minimize energy consumption while improving quality of air

Taking fresh air from outside is the best approach we can follow to improve air quality, but outside temperature is not going to be always good. If its too cold outside and we take that air in for ventilation then room temperature will start dropping which will put pressure on heating system and in turns consume large energy. To tackle this we are first monitoring the outside temperature and we are using outside air only when the outside temperature is within acceptable range otherwise we are ventilating air within the rooms.

5.2 Handling Short cycling

Preventing short cycling of the system by not turning it on and off faster than its specified rate was a challenge. When occupant is not in the room for long period of time then improving air in such room will not be of any use. So we had to handle such rooms which are used for short durations of time. As per our model, process of air conditioning will not start immediately as occupant enters the room, it will wait for 1 minute and if the occupant is still there then it will start the ventilation if the air quality is not good. So if the occupant comes and leaves the room frequently then system will not keep shutting on and off.

5.3 Reducing air pressure in the room

When you transfer air from one room to another it creates a pressure in the room to which we are transferring air due to excess of air in the room. To reduce this pressure we have to move some air out of the room. So we have handled this with 2-way air transfer. While taking good air from other room we are also moving bad air to the same room so pressure does not increase or decrease in both of the rooms.

5.4 Future Prediction of occupancy

Predicting future occupancy so that we can improve air quality beforehand was a challenge. We can draw many different patterns depending on the historical occupancy data.
and we can use that pattern to predict the occupancy.

6 Conclusion

Use of occupancy detection can minimize the energy consumption in air ventilation system, also we can improve user comfort by accurately predicting future occupancy. The system can take decision to turn on and off depending on the occupancy. As the system will shoot up only when it detects the occupancy, it reduces the power consumption and thereby saving energy. Thus, the designed system improves the air quality and consumes less energy.

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