Development of Intelligent Air-conditioning System

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Abstract

This paper presents an air-conditioning system that regulates room temperature via the use of multiple-sensor system that is named as “Intelligent Air-Conditioning System”. Air-conditioning system has become one of most important human comfort technologies especially for countries near the equator. Conventional methods of regulating room temperature by air-conditioning system using single sensor have been integrated into most of today’s split type and window type air-conditioner. The demands from customer now from air condition technology are for more human comfort, energy saving and smart gadgetry thus the trend in research is to incorporate artificial intelligent technology in this field. However, many research in this area concentrate on maximizing the use of a single located near the air intake area of the air-conditioning system. In this paper we present a case for the use of multiple sensors to determine the temperature distribution more accurately throughout the room and creating a system that will provide a higher degree of human comfort with less energy consumed.

1 Introduction

In commercial buildings and private home it is common to control room temperature with a single heating, ventilating, and air-conditioning (HVAC) unit and controller. Systems configured this way are most commonly controlled with a single sensor in one of the rooms. The controller gets the temperature reading from one of the sensors, and supplies heating or cooling to all other parts of the rooms proportionally.

This method assumes that all parts of the rooms have the same load all the time, and therefore the same temperature throughout. This is often a poor assumption, which leads to discomfort and more energy consumption than necessary. The reason for controlling room temperature with a single controller and a single sensor is cost.

It is expensive to install a separate HVAC unit and controller for each part of room. It is also expensive to install temperature sensors in every corner of the room, primarily because of the cost of running wire to the sensors. New technology, particularly wireless sensor technology, offers the opportunity to significantly reduce the cost of sensors such as those used to control space temperature in commercial buildings and private homes. However, the actuation parts of the system will still expensive for the foreseeable future.

In this paper, investigation on the potential benefit of replacing a single temperature sensor used to control temperature in a room with a sensor network that provides one sensor per area of the room.

However, the actuations do not change. There is still just one controller and one HVAC unit for the room. To our knowledge, the energy and comfort implications of this problem have not been analyzed. Most multiple sensor control problems have focused on fault tolerance [1] or multi-target problems [2, 3].

The problem addressed in this paper is like a multi-target problem where not all of the targets can be satisfied since there one actuator. The focus of the paper is on how to make use of the additional information available from the network of sensors, and an evaluation of how different methods of using the information affect energy performance and thermal comfort.

In this paper a system to analyze the effectiveness of multiple-sensor configuration is laid out. The system is designed to be implemented by any air-conditioning system that has integrated vane system to direct air-flows from the air-conditioner[6]. It can be aimed at optimizing comfort, or minimizing energy consumption subject to constraints on comfort.

The next section describes the set-up of the experimental system after a brief statement about the objectives of this project. The subsequent section describes the hardware implementation of the system. In the next section the results of the experiment and its analysis are presented.

1.1 Project Objectives

This project aims at developing and implementing an intelligent air-conditioning which is effective as well as reliable to meet human comfort. The emphasis during the development process will be laid on the efficiency of the system to minimize the time the actuator is switched on. The human comfort for this part of the project will be to ensure an even distribution of the room temperature via controlling the vanes to direct air-flows to selected target.

2 Modelling the System

In order to set-up the system a room has been converted into an air-conditioning test system. The rooms are to be set-up to test for the effects of air exchange, conduction through walls and fenestration, solar radiation, energy storage in furniture, and internal loads from occupants and equipment. It can predict both transient and static behavior of the system. The room model is modular so that elements can be adjusted to suit the experiments.

Figure 1: Approximate sensor location

Figure 1 shows the diagram of the room with approximate location of the sensors. The room has five modules: walls, windows, ceiling, floor, and air. Each room has three heat transfer inputs: internal loads and outdoor temperature.

3 System Implementation

The system as laid out in figure 2 consists of microcontroller to coordinate all the functions in the air-conditioner with inputs from temperature sensors [4]. Two stepper motor controls the air directional vane control. Three speed AC Motor acts as blower to supply cool air to the room and compressor.

First, once the air-conditioning start running, the controller will be provided with temperature information from the sensors attached from the ceiling. From this temperature gradient of each sensor, microcontroller will change the direction of air vane to hottest area to ensure the temperature will be evenly distributed. The room temperature is set manually by the user via a remote controller in the range of 18 ºC until 25 ºC. The fan speed and the cooling type will be controlled by the controller base on the environmental conditions.

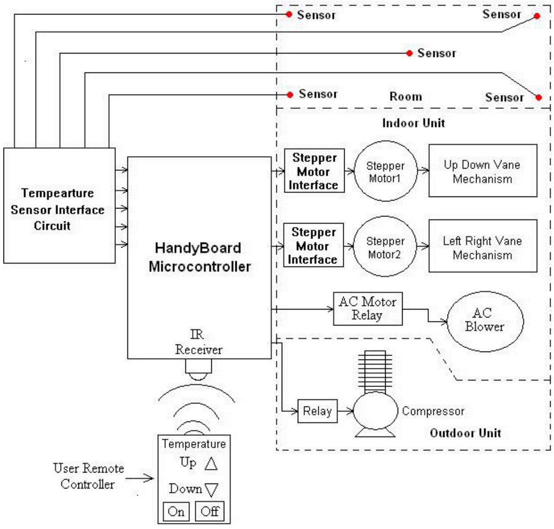

Figure 2: Functional block diagram

The horizontal air swing will be controlled by an angle θ to reach the air to these sensor zones [5]. So there will be the five position of horizontal air vane which will be moved by a pair of stepper motors. The vertical air vane will swing constantly through out the control process.

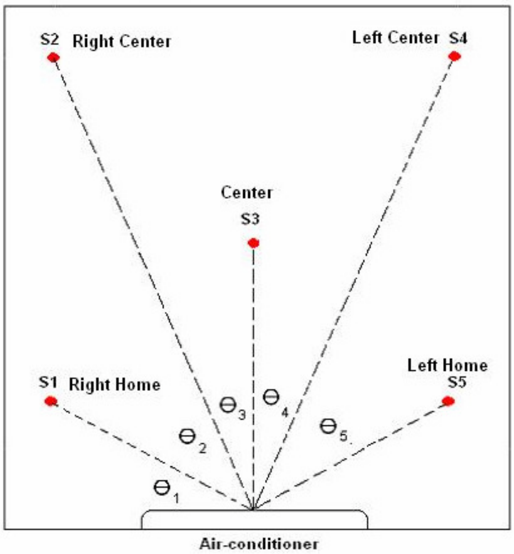

Figure 3: Vane directions

The process flow of the system is shown in figure 4. The objective of the control system is to maintain the room temperature according to the feedback signal from the temperature sensor [7]. Once the controller is switch on, the controller will control all the stepper motors, blower and the compressor according to the room comfort condition. The compressor would only stop, after all temperature sensors reach the set temperature. The stepper motor will drive the vane mechanism to guide the air direction according to the sensors position. The microcontroller also control the AC motor blower speed. So that room temperature will be automatically maintain by microcontroller through feedback sensors from the room.

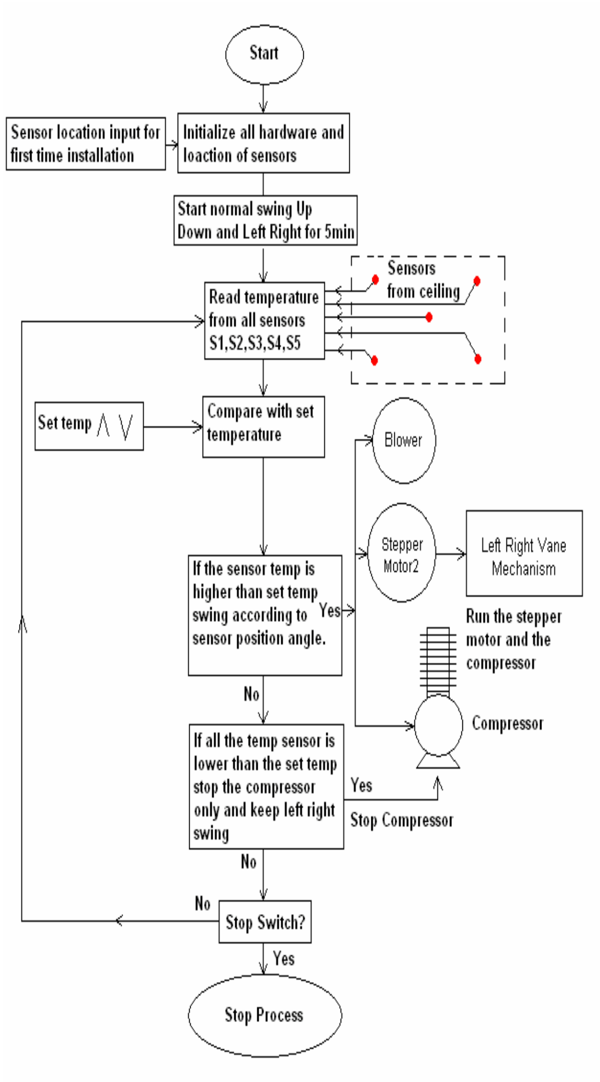

Figure 4: System process flow

4 Results and Analysis

The following graph shows the test results of the intelligent air-conditioning system. The first experiment is to test the performance of the system with regards to outside temperature. The system has been tested at different time from morning to evening to test its reaction the input of the external temperature.

The outside temperature for the morning session is **29.3°C** and peaked at noon with the 32°C. Temperature in the evening is 28°C and rise again to 29.3°C at night. The system is set to 24°C, and independent measurement indicates that the room temperature is maintained at an average of 27°C throughout the day.

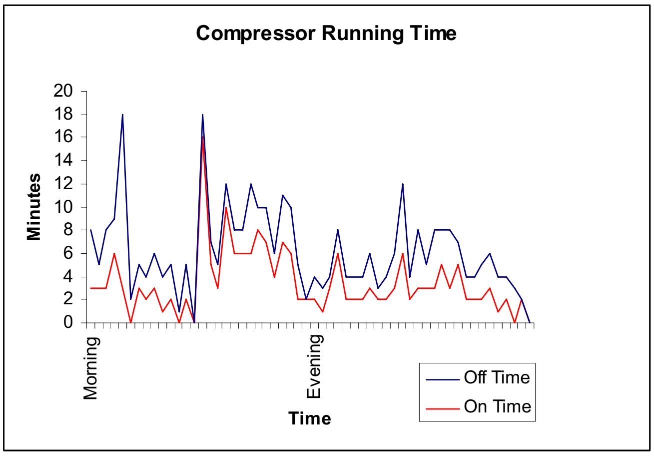

Figure 2: Compressor "ON" and "OFF" time

The average running time of the compressor is 3.4 minutes for the period of the day and the average time it is in the off state is 2.9 minutes. The standard deviation showing the variation in time between the on states is 2.7 and the standard deviation for the system to be in the off state is 2.08.

If we segment the period of testing into morning (8.00am to 10.00 am), noon (11.30 am to 1.30pm), evening (4.00 pm to 6.00pm) and night (8.00pm to 10.00pm) the average on time will be at noon with 6.2minutes and the least on time is in the morning with 2.2 minutes.

To test the internal load a test for number of people affecting the sensors. From the results gathered the number of people affects the system according heat generated by occupant and the time for the system to reacts is displayed in table 1.

Number of people	Time to react to sensor
1 person	10.6 min
2 persons	6.3 min
3 persons	4.2 min
4 and above	3.2 min

Table 1 Sensor reaction time vs no of people

The following table shows how long the system will take to stabilize temperature when the number of sensors varies. It take longer as each of the sensor will be sprayed with cool air until

Number of Sensors	How long the system will take to stabilize the change in temperature
1 Sensor	66 Sec
2 Sensors	137 Sec
3 Sensors	213 Sec
4 & 5 Sensors	350 Sec

Table 2 Sensor reaction time

4 Conclusions

This paper reports two significant findings regarding the use of multiple sensors for controlling systems with a single actuator. The first is that using multiple sensors can result in simultaneous energy savings and comfort improvement. The second is that not all strategies for using multiple sensors work better than a single sensor strategy.

In this paper the temperature distribution for human comfort is achieved through the control of air conditioner flaps or vane control. The resulting temperature distribution for the whole room is almost uniform because of using several sensors through out the room and the air blowing direction is changing according the hotter zone.

Further work in this area will include the use of other control strategies such as fuzzy logic and neural system to increase the capability of the rule based system demonstrated here. The experiment set up shall also include multiple rooms to increase the

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References

[1] Hsu P.L., K.L. Lin, and L.C. Shen, 1995, “Diagnosis of Multiple Sensor and Actuator Failures in Automotive Engines”, IEEE Transactions on Vehicular Technology Vol 44 (4) 779-789 November 1995.

[2] Shamseldin, A., B. J. Black, and E. O'Brien, 2000, “Multiple-sensor weigh-in-motion of road vehicles using a neural network algorithm.”, Computational Engineering Using Metaphors from Nature, Leuven, Belgium 53-8. Sept. 2000.

[3] Rothrock, R.L. and O. E. Drummond, 2000, “Performance metrics for multiple-sensor multiple-target tracking.”, Proceedings of the SPIE - The International Society for Optical Engineering, vol.4048 521-31, 2000

[4] Dogan Ibrahim (2002). Microcontroller Based Temperature Monitoring and Control. 1st edition: Newnes

[5] Wang, Shan K Shan Kuo (1993). Handbook of Air-Conditioning and Refrigeration. 3rd edition: McGraw-Hill

[6] Mackenzie, I. Scott (1992). Microcontroller. 4th edition : Merrill

[7] Chichester (1992) Intelligent Sensor Technology 1st edition: Wiley