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Thermal Comfort Management of a Single Office Room via Air Flow Controls

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Abstract: This paper presents an intelligent air-flow controller for Air-Conditioning (AC) system in a single office room environment. The prototype is capable to adjust the split unit AC system air-flow under dynamic temperature variations caused by the occupant's movement, thus, maintaining an optimal comfort level for a room. In this study, two ultrasonic sensors installed in a typical 1 hp split unit AC system that senses the occupant movement inside the room. Based on the occupant's movement, a microcontroller will adjust the fin (air-flow) accordingly via an installed two units of servo motor. The primary goals of the prototype are to reduce the electricity consumption of the AC system while maintaining an optimal comfort level of the occupant. The system performance successfully evaluated through autonomous air-flow control of an AC indoor unit fin adjustments in a single occupant movement scenario.

Keywords: Thermal comfort; Air-flow controller; Building Management System; Control

1.0 INTRODUCTION

Commercial office buildings consumes the largest amount of electricity globally [1]. The energy consumptions dominated by the Heating, Ventilating and Air-Conditioning (HVAC) system. Therefore, it is essential for installation of an energy management systems that includes AC controls. An intelligent thermal comfort management in an office building should aims to perform controls that provide optimal trade-off between comfort level and energy cost.

There have been extensive studies performed in thermal comfort management of an office building that includes assessment studies and control strategies. M.B.A Aziz et al. studied air-conditioning energy consumption in an education building through assessment studies in order to increase awareness among occupants and for controller development [2]. Moreover, Jonas Hinker et al. assessed the issue of thermal comfort in residential buildings in order to develop a distributed controller [3]. Additionally, Sindhu S. Shetty et al. studies the impact of personal fans with respect to room temperature in order to create a framework for optimal thermal comfort in building [4]. Huafen Hu et al. uses low cost sensing system in order to improve building energy efficiency [5].

There also has been extensive studies utilizing classical control methods and advance control for optimal comfort management in building [6]–[8]. An example of the use of classical control is shown by Ricardo Forgiarini Rupp et al. that uses PID controller to control the heating system emission of a building [9] . Meanwhile, there were many researchers adopts advanced control techniques such as Model Predictive Control (MPC) techniques, Genetic Algorithm (GA) and Fuzzy to optimize heating, lighting and shading in a building [10]–[13]. Moreover, hybrid techniques were also shown having robust performances in for thermal comfort controls in building such as Fuzzy-PID and GA-Fuzzy controller [14], [15].

This paper is organized as follows: Section 2.0 discusses the project methodology. Meanwhile, Section 3.0 presents results related to this study. Section 4.0 discusses the results and covers on the project scope. Finally, Section 5.0 concludes this paper while mentioning future works related to study.

2.0 MATERIALS AND METHODS

This block diagram of this study is shown in Fig. 1. The system detects the occupant's movement inside the room via two ultrasonic sensors. Each one the ultrasonic sensor is used to detect the occupant' location with respect to the AC location. Then, the ultrasonic sensor reading will be used to control two units of servo motors. The servo motors were used to move the AC fin to direct the air-flow from the AC directly towards the occupant. The ultrasonic sensors continuously detect the movement of the occupant to have

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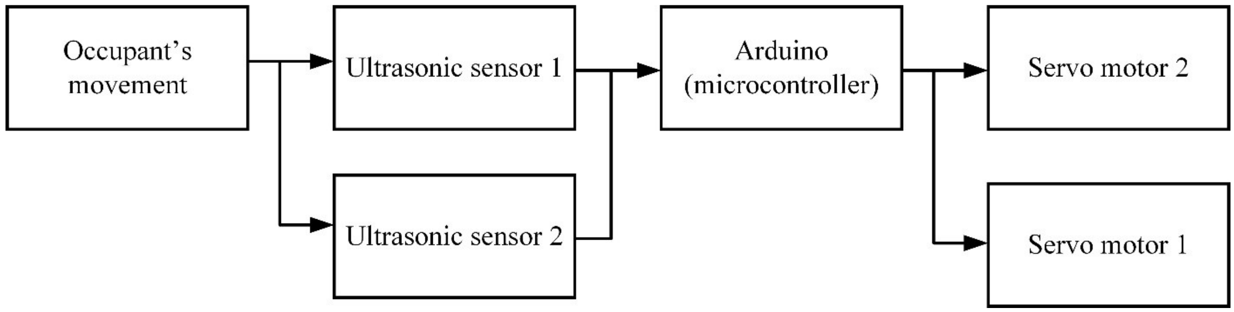

Fig. 1. Block diagram of the air-flow controller.

optimal air-flow direction in the room. Three possible movement considered in this initial study as shown in Fig. 2.

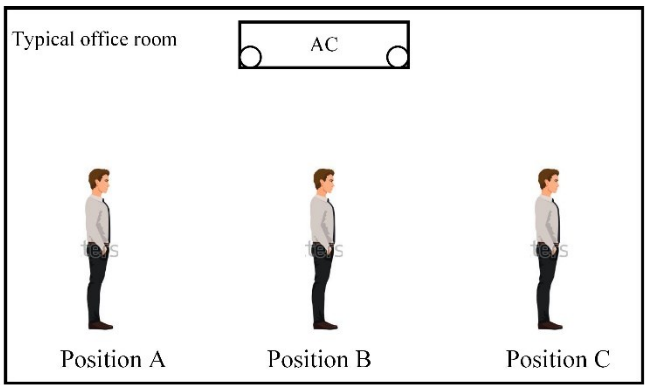

Fig. 2. Scenarios for air-flow control.

Position A is when the occupant is on the left of the AC unit and the air-flow needs to be directed to the left side. Position B is when the occupant is at the middle of the AC unit where direct air-flow is needed. Meanwhile, position C is when the occupant is at the right of the AC unit and the air-flow needs to be directed to the right-hand side. Based on this pre-defined movements, the air-flow can be directed to the occupant regardless whether they are moving from left-to-right, right-to-left or remain stationary in any side of the AC unit in the room.

The actual prototype of an AC indoor unit equipped with an air-flow controller is shown in Fig. 3. The intelligent air-flow control prototype diagram is shown in Fig. 4. Two ultrasonic sensors are located at each sides of the AC unit. Meanwhile, servomotors are located at each side of the air-flow control fin. The schematic of the system is shown in Fig. 5.

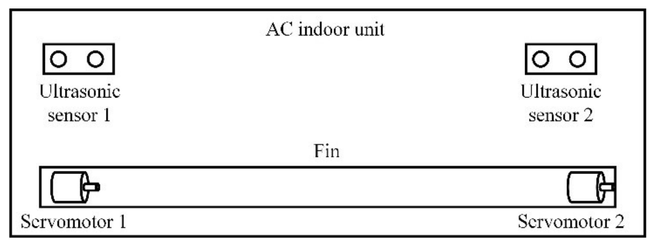

Fig. 4. Air-flow controller architecture.

The operation principle of this system depends heavily on the two ultrasonic sensors to detect the occupant movement either from left to right or from right to left. The sensor operates based on ON/OFF outputs. If the sensor detects occupant presence within its sensing radius, it will transmit the information to the microcontroller. If the sensor does not detect occupant presence, the fin will be adjusted accordingly by the servomotors. Hence, the air-flow will be directed towards to occupant's location in the room. The flow chart of the system operation is illustrated in Fig. 6.

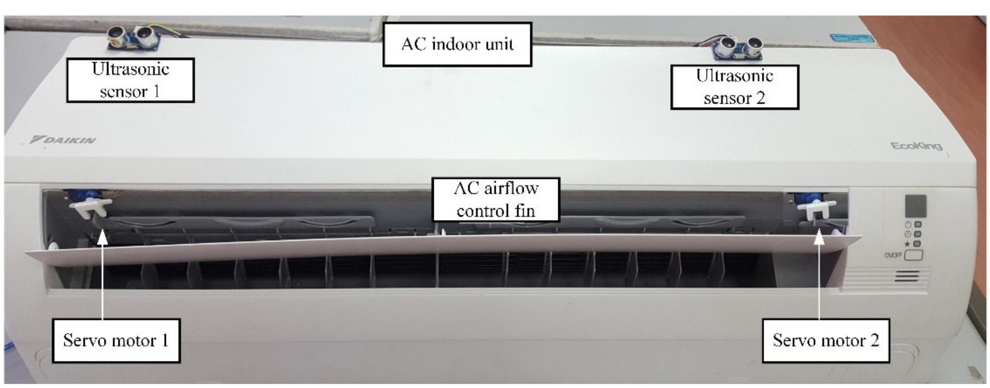

Fig. 3. Air-flow controller prototype.

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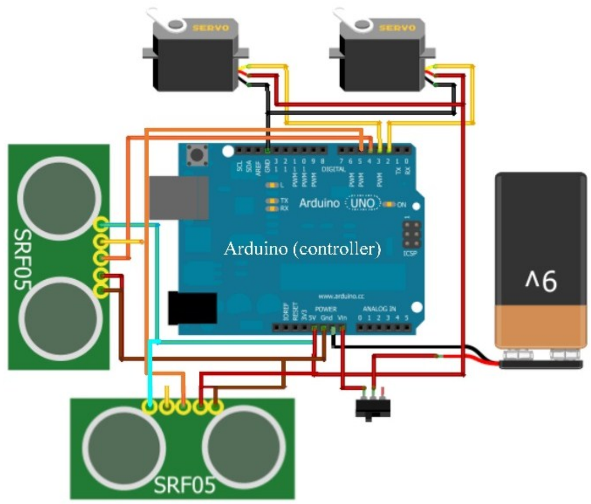

Fig. 5. Schematic diagram of an air-flow controller.

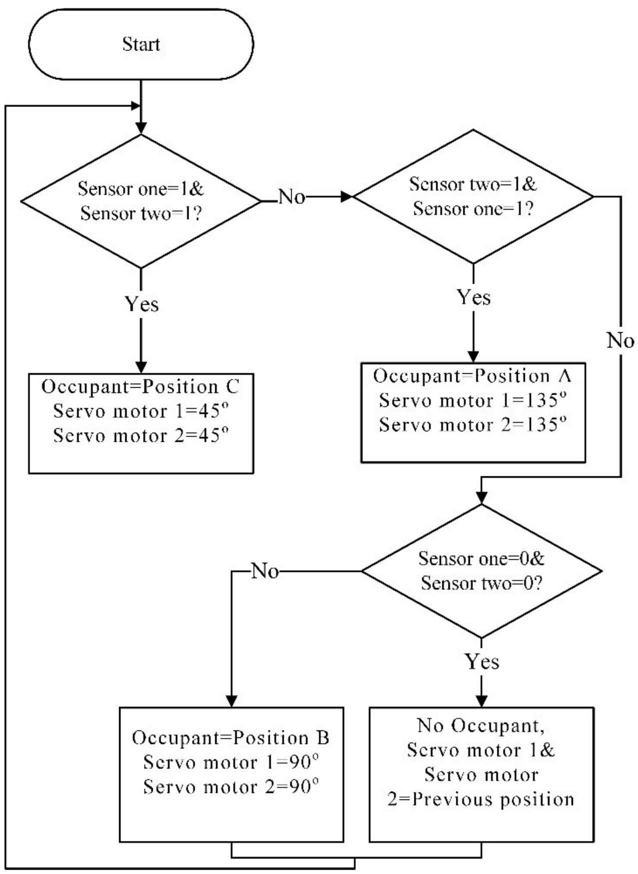

Fig. 6. Flow chart of the air-flow controller operations.

As illustrated in the flow chart, the system will continuously measure the sensors output to determine the location or movement of the occupant. If sensor one detects occupant followed by sensor two, the microcontroller sent commands to the servo motor to vary it angles to 45º (position C). However, if sensor two detects occupant presence followed by sensor one, the servo motor will adjust it angles to 135º (position A). If only one of the sensors detect occupant's movement but does not followed by another sensor, the servo motors angle will be adjusted to 90º (position B).

3.0 RESULTS

The results collected from this work only focuses on evaluating reliability of the system operation. Several scenarios were tested based on the occupant's position and movements inside the room. The results are presented in Table 1.

Table 1. Air-flow controller performance

Scenario	Servo Motor 1 (º)	Servo Motor 2 (º)
Position A	135º	135º
Position B	90º	90º
Position C	45º	45º

As shown in Table 1, the initial system works according to pre-defined occupation locations. Hence, an optimal air-flow direction can be achieved in the office room.

4.0 DISCUSSION

In this work, only simple operations were considered to evaluate the feasibility of the system for single office room installation**.** Advanced scenarios such as multiple occupants are not covered in this paper. This study is an initial study for development of an intelligent air-flow control that will includes several additional sensors such as temperature and humidity. Furthermore, additional servo motors also will be incorporated when using larger than 1hp AC indoor unit.

5.0 CONCLUSION

The goal to develop a simple and low-cost air-flow controller for a single office room has been achieved in this study. The system operates successfully under single occupant conditions. Moreover, the system reliability also has been evaluated through several scenarios of occupant's location and movement inside the room. Future works includes incorporation of multiple sensors and operations under multiple occupant scenarios. This paper only present in development of air-flow controller prototype. Further analysis such as potential energy saving is not covered in this paper.

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