Original article

Experimental Studies of Automate Temperature and Relative Humidity Control System to Minimize Adverse Health Effects

Received: Nov 11, 2019;
Accepted: Dec 12, 2019;
Published: Dec 25, 2019

Pornpawee Thongkhome [1,*] and Sompoch Veangkum [2]
[1]Triamudomsuksa Pattanakarn School [1]
[2] JFAC Training center

Abstract

Relative humidity is directly related to human thermal comfort. Relative humidity also has indirect effects on the growth and existence of contagious diseases and allergies, especially within the enclosed area where the air-conditioning system has been installed. However, the air-conditioning system can only control the temperature at a stable level; typically, an air conditioning system cannot automatically control relative humidity. The system still needs a special device to increase or reduce relative humidity, which would increase the cost of the system.

The objective of this research is to improve and investigate the effectiveness of split-type air-conditioning system to control relative humidity (RH) and temperature level in the bedroom by using a low cost, newly designed large memory microcontroller unit sensor. This sensor would cooperate with air-conditioning system to control bedroom temperature and relative humidity within the range 25ºc ±1ºc and 55% RH ±1.5% RH. This range was chosen to reduce the indirect effect of relative humidity on the occurrence of allergies and the existence of diseases. The sensor detects the temperature and relative humidity within the bedroom and sending the commands to the air-conditioning system to adjust these parameters through an infrared blaster. The sensor operates on an automated, changing operation mode that can turn on the drying mode of the air-conditioning system to dehumidify the air in the bedroom. The tested bedroom in this study was 16 m^2 with a 12,000 BTU air-conditioning system for system performance evaluation.

In this experimental study, the air conditioner initially operates in cool mode. If the bedroom's relative humidity is over than 60%RH, the sensor will automatically send the command to change the air-conditioner to operate under dry mode until the relative humidity is reduced to close at 55%RH +1.5% . After reaching the optimum humidity, it will switch back to run at its initial setting again. In contrast, if the bedroom's relative humidity is lower than 50%RH, the sensor will automatically send the command to increase the air-conditioner's temperature setting by 2ºC under cool mode, until the relative humidity is close to 55%RH -1.5% . After reaching this RH, it will swap back to it initial setting. This operation procedure will continue until the user turns off the bedroom air-conditioning system. Our hypothesis is that the newly designed air conditioning system with the large memory microcontroller unit with an improved sensor improvement could control temperature and relative humidity in the bedroom to keep steady at average ±0.65ºC from setting temperature and at an average relative humidity of 56.15 % RH..

Key words: Health Effects, Temperature and Humidity Control, Thermal Comfort

Corresponding Author: * Pornpawee Thongkhome, Triamudomsuksa Pattanakarn School Office Email: pornpraweeth@gmail.com Tel. 087-996-3493

Introduction

The purpose of this experiment is to minimize indirect health effects of relative humidity that impact some people who are living in bedrooms with installed air-conditioning systems. Some people suffer from nasal obstruction, nose or eye irritation, sore throat, cough, and other symptoms due to non-optimal humidity from air-conditioning systems. Air conditioning systems also directly affect human thermal comfort, which is the reaction that a human feels about heat and cold (Holm D & Engelbrecht FA,2005). Relative humidity also affects the growth and existence of diseases, contagious diseases, and allergies, and organismis causing diseases such as bacteria, fungi, viruses, and protozoa (Baughman & Arens,1996).

Sometimes it is more beneficial to use the air-conditioning system on "Dry Mode," which is an air-conditioner function that efficiently extracts humidity from the bedroom. Using Dry Mode will cause the fan in air-conditioner to operate at a slower speed, resulting in a cooler evaporator coil that condenses water vapor as the air-conditioner blows out the dry air through the appliance. In general, people manually use their air-conditioner remote control to swap between Dry or Cool Mode. This is due to the fact that air conditioners usually do not have an automated function that switch between Dry or Cool mode in response to humidity chages in the bedroom. However, a feature to automatically move between Dry or Cool mode would be ideal because people cannot wake up to adjust the air-conditioner's humidity mode at night.

In the previous work, the researchers designed a new, low-cost temperature and relative humidity sensor to read present temperature and relative humidity within the bedroom. This sensor also automates the adjustment of temperature and relative humidity parameters by sending the commands to the air-conditioning system through an infrared blaster. This system automatically turns on the drying mode of the air-conditioning system to dehumidify the air when relative humidity is too high (Thongkhome & Veangkum,2019). This previous study showed that this new system with a temperature and humidity sensor could keep control temperature and relative humidity to keep steady at average ±0.65°c from setting temperature and relative humidity at average 58.02% RH by automatically switching on dry mode air-conditioning system when needed. However, the average % RH is the marginal relative humidity control. There are limitations of the selected microcontroller unit's internal memory of sensor that should impact with the commands being sent through the infared blaster to the air-conditioner. For example, it is important a person operating or designing the air conditioner precisely adjust air-conditioning system parameters like fan speed or provide for some temperature range to flexibility control relative humidity in the bedroom. So, this research article would like to offer another methodology to improve sensor performance.

Research Methodology

We designed a new, low-cost temperature and humidity sensor to operate with an air-conditioning system to automatically change its operation mode to the drying mode and cooling mode. The system contains an Arduino Pro Mini microcontroller board as the main controller unit. It also uses an element sensor DHT22 to read the present temperature and humidity of the bedroom and to send the commands to the air-conditioner via an infared (IR) blaster that functions like the air-conditioning system's remote controller. One advantage of this microcontroller unit board is its special small size (8 mm x 33 mm). Another good feature is that power consumption goes down to 23 µA (0.023 mA) with the 5 V in power-down sleep (PDS). Thus, this system is more efficient than other microcontroller units, and suitable to use as a standalone implement in a designed system. But, the drawback of the microcontroller is the large amount of data or the long length of command that must be sent for changing each operation mode of the air-conditioning system. Each signal may contain up to 228 bits per command because it contains a lot of information like temperature, fan speed, sleep timing, swing style, etc. However, the Arduino Pro Mini has only 2K SRAM to manipulate variables when it runs. This is not enough memory to completely support changing operation mode that was demonstrated in a previous experiment. For these reasons, we chose another microcontroller unit board to support these requirements. We selected the Arduino Mega microcontroller unit board for better storage options. Figure 1 shows the device specifications for both the Arduino Mini and Mega. It has large memory of 8K SRAM to manipulate the IR blaster command variable and to completely control and change air-conditioning system operation when necessary. But the disadvantages of Arduino Mega microcontroller unit board are its large board size (53.3 mm x 102 mm) and higher power consumption (3.9 mA with 3.3 V, PDS mode, disable or bypass some onboard components) than Arduino Pro Mini board.

The block diagram of newly designed with a large memory sensor microcontroller unit sensor is shown in Figure 2 & 3 show the prototype picture of newly designed sensor in this experiment.

Boards	Microcontroller	Operating Voltage/s (V)	Digital I/O Pins	PWM Enabled Pins	Analog I/O Pins	DC per I/O (mA)	Flash Memory (KB)	SRAM (KB)	EEPROM (KB)	Clock (MHz)	Length (mm)	Width (mm)	Cable	Native Network Support
Uno	ATmega328	5	14	6	6	20	32	2	1	16	68.6	53.4	USB A-B	None
Leonardo	ATmega32u4	5	20	7	12	40	32	2.5	1	16	68.6	53.3	micro-USB	None
Micro	ATmega32u4	5	20	7	12	40	32	2.5	1	16	48	18	micro-USB	None
Nano	ATmega328	5	22	6	8	40	32	2	0.51	16	45	18	mini-B USB	None
Mini	ATmega328	5	14		6	20	32	2	1	16	30	18	USB-Serial	None
Due	Atmel SAM3X8E ARM Cortex-M3 CPU	3.3	54	12	12	800	512	96	×	84	102	53.3	micro-USB	None
Mega	ATmega2560	5	54	15	16	20	256	8	4	16	102	53.3	USB A-B	None
M0	Atmel SAMD21	3.3	20	12	6	7	256	32	×	48	68.6	53.3	micro-USB	None

Figure 1. Device specifications for Arduino Mini and Mega microcontroller boards

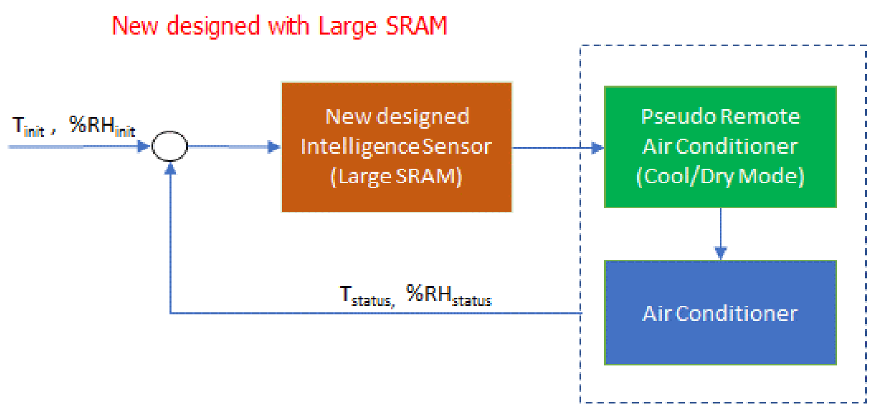

Figure 2. Block diagram of newly designed sensor system

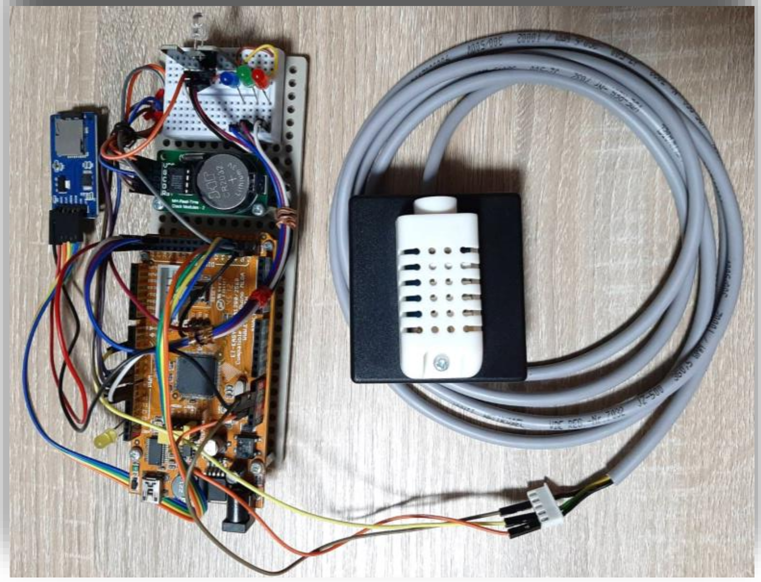

Figure 3. The full system newly designed with large memory microcontroller unit sensor

Study Population and Sample

The bedroom size was about 4 x 4 x 2.2 meters. In this experiment, we installed a 12,000 BTU air-conditioner. The bedroom was located on the 3rd floor of a 3-story townhome containing 2 walls with mirrors and 2 walls made of concrete.The bedroom layout is represented in Figure 4. Each night 3 people live in the bedroom. The researchers used both the old newly designed sensor and the newly designed with a large SRAM sensor to collect data for the temperature and relative humidity of the same bedroom (Figure 5).

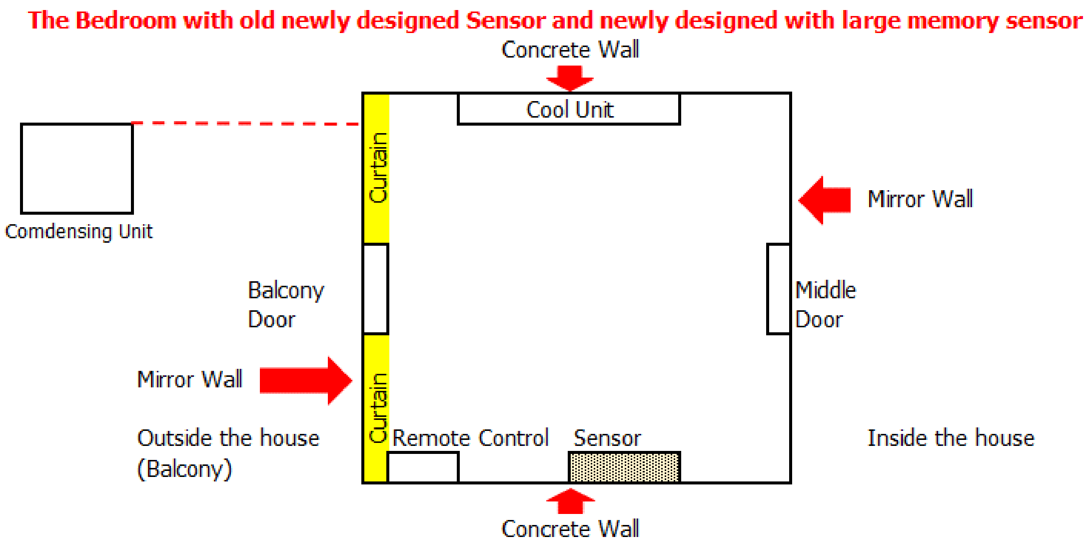

Figure 4. Bedroom layout in the experiment

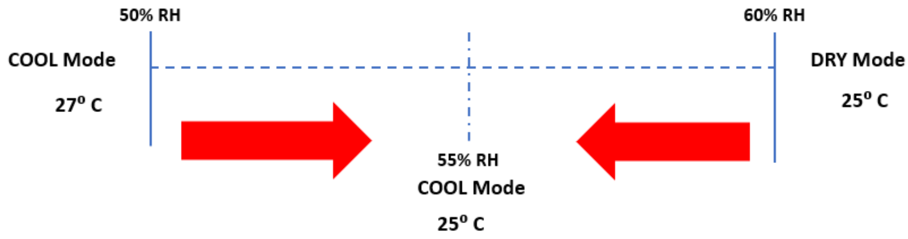

Figure 5. Dehumidify Method

Study Design

The newly designed with larger memory sensor was designed to control bedroom temperature and relative humidity with the dehumidify method that is shown in Figure 5. This method aimed to control the temperature and relative humidity to close the target at 55% relative humidity (RH) and 25° C cool mode. Normally, the users initially start to operate air-conditioners with cool mode per their setting temperature requirement. When the bedroom relative humidity is running higher than 60% RH, the sensor will automatically send the command to change the air-conditioner to operate under dry mode until the relative humidity is reduced to 55% RH +1.5%. Then it will swap back to run at the initial setting again. In contrast, if the bedroom's relative humidity is running lower than 50% RH, the sensor will automatically send the command to increase the air-conditioner 's temperature setting to +2°C under cool mode until the relative humidity is increased to close at 55%RH -1.5%. Then it will swap back to run at initially setting as well. This operation procedure will continue until the user turns off the bedroom air-conditioner.

Data Collection

The temperature and relative humidity measurements in the bedroom are collected every night for 4 weeks using both sensor types from 22:00 pm at night on one night until 05:00 am on the next day. The temperature and relative humidity raw data that are received from the sensors will be kept in the system's SD (secure digital) cards' data loggers every 15 minutes (28 data points per night) for further data analysis.

Data Analysis

For newly designed sensor with larger memory microcontroller unit 's performance evaluation, we used the average temperature offset from setting temperature of the bedroom's air-conditioning system. We also used the average relative humidity in each day within the same period time as comparison. This was done to control for relative humidity within the optimum range.

Results

The raw temperature and humidity data from the old newly designed (sensor#1) and the newly designed sensor with large memory microcontroller (sensor#2) were shown in Table 1, and Figure 5 & 6. Table 2 represents the average temperature and humidity for each data collection method. Statistical analysis comparing results from the old newly designed (sensor #1) and the newly designed sensor with large memory microcontroller is shown in Table 3. In Table 3, the ANOVA analysis showed that the means for the relative humidity, expressed in a percentage, were not significantly different from each other ($p > 0.05$ for 95% confidence interval). But the results of the Levene test showed that their variances were significantly different (p-value < 0.05 for 95% confidence interval), and that the sensor #2 was more effective. In Figure 3, the observed relative humidity of the newly designed sensor with large memory microcontroller and the old newly designed sensor both showed relatively stable relative humidity readings. However, the newly designed sensor's relative humidity was closer to the target goal of 55% RH ±1.5% than old newly designed sensor per hypotheses.

Table 1 Temperature and Humidity data from 2 differently designed sensors

Seq.	Room Temp	Room Humidity	Room Temp Sensor #1	Room Humidity Sensor #1	Room Temp Sensor #2	Room Humidity Sensor #2
1	27.57	55.92	28.88	56.98	25.66	56.14
2	25.97	52.68	26.16	51.18	25.86	54.48
3	25.39	53.41	25.8	49.75	25.74	57.04
4	25.91	58.12	26.2	55.36	25.86	56.22
5	25.63	61.58	26.08	60.45	25.14	59.48
6	25.81	61.04	25.48	57.42	25.42	57.51
7	25.61	60.49	25.68	61.24	25.66	56.65
8	25.79	60.22	25.36	55.57	25.42	58.51
9	25.76	61.68	25.68	56.08	25.98	56.84
10	25.73	63.19	25.36	57.23	25.26	55.31
11	26.11	62.93	26	56.84	25.74	56.57
12	26.05	65.58	25.64	53.05	25.94	56.44
13	25.93	65.45	25.68	57.95	25.58	55.86
14	25.77	64.9	25.2	58.97	25.54	56.82
15	25.89	64.76	25.4	58.88	25.74	53.20
16	26	66.45	25.76	58.91	25.82	56.77
17	26.01	67.41	25.6	59.37	25.9	56.55
18	26.03	65.05	25.52	59.52	26.1	54.29
19	26.19	66.76	25.8	61.53	26.26	57.22
20	26.11	67.24	25.76	57.96	26.1	57.07
21	26.07	64.9	25.64	57.59	26.14	55.00
22	26.11	67.7	25.8	63.61	26.1	57.33
23	25.91	67.55	25.4	60.39	25.82	57.83
24	25.83	65.9	25.16	55.06	25.86	55.21
25	25.88	68.73	25.32	62.70	25.82	57.93
26	25.75	67.87	25.2	63.65	25.54	58.13
27	25.81	67.06	25.36	54.63	25.62	55.78
28	25.95	70.43	25.52	62.92	25.74	59.58

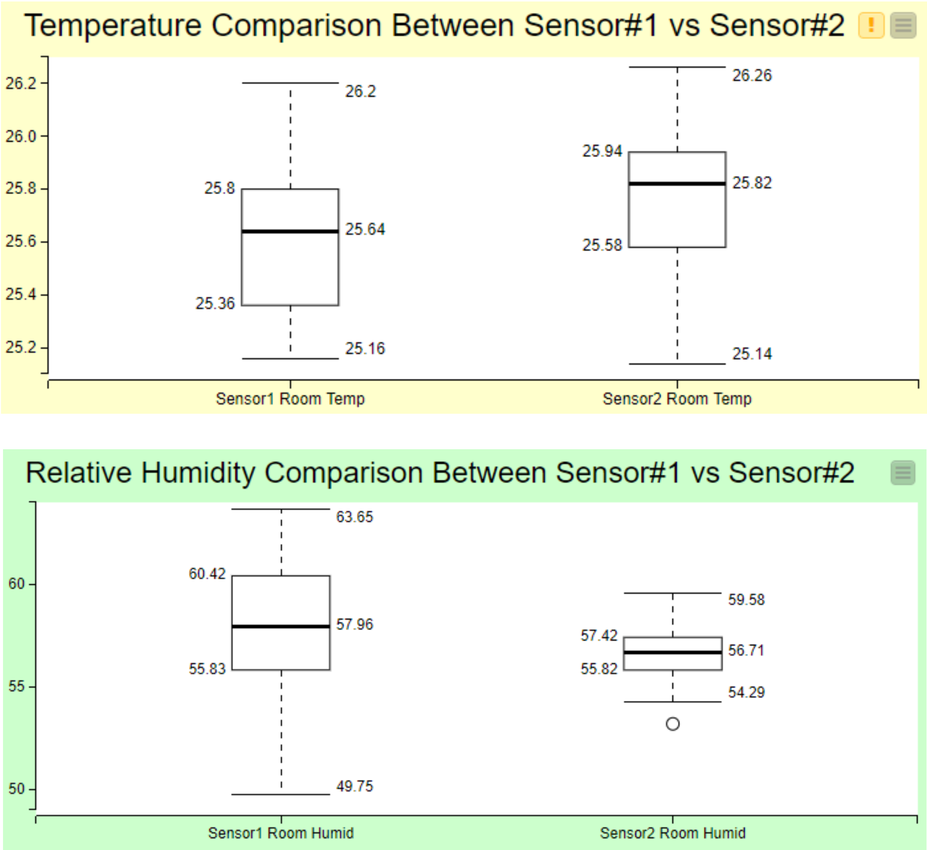

Figure 5. Box plots for temperature and relative humidity data from 2 differently designed sensors

Table 2 Descriptive table of temperature and humidity data from 2 differently designed sensors

One-way analysis of variance (ANOVA)

Descriptive Statistics

Confidence Interval (CI) Probability: 99.0%

	Group	N	Missing	Missing Group	Mean	Std. Deviation	Std. Error	CI (Lower Bound)	CI (Upper Bound)
Humidity	Sensor1 Room Humid	28	0	0	58.0282	3.4971	0.6609	56.1971	59.8593
Humidity	Sensor2 Room Humid	28	0	0	56.6343	1.4639	0.2767	55.8678	57.4008
Humidity	Total	56	0	0	57.3312	2.7478	0.3672	56.3515	58.311

8

Table 3 Levene test and ANOVA analysis result of 2 sensors

Levene Test

The Levene Test is used to test for the equality of variances.

	F	df 1	df 2	p-Value
Humidity	13	1	54	0.0007

ANOVA

	Source	Sum of Squares	df	Mean Square	F	p-value
Humidity	Between Groups	27.2025	1	27.2025	3.7853	0.0569
Humidity	Within Groups	388.0605	54	7.1863		
Humidity	Total	415.263	55			

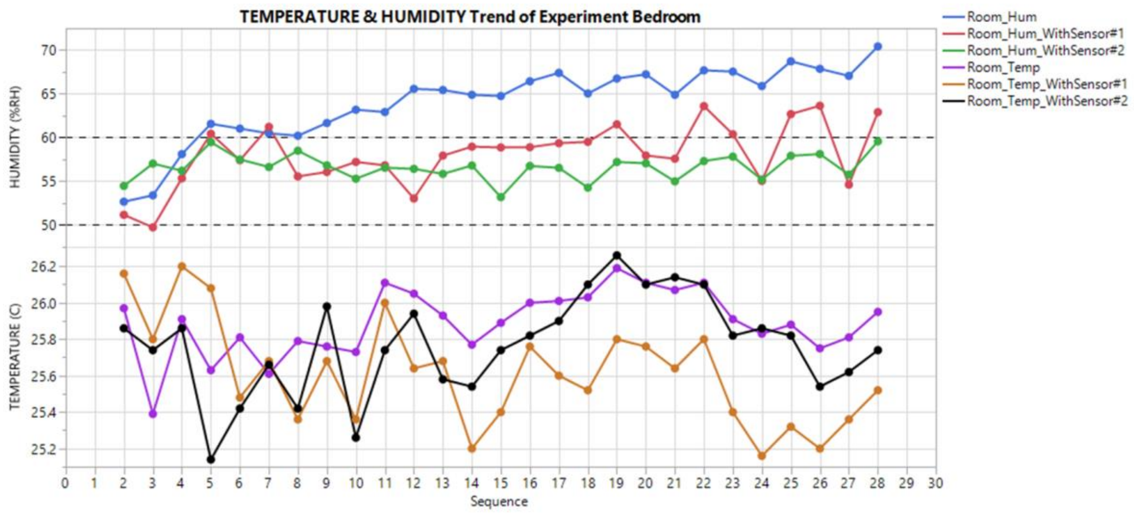

Figure 6. Temperature and relative humidity data from 2 differently designed sensors over sampling time period

Discussion and Conclusions

This experimental study found that the dry mode air-conditioning system is more effective at extracting humidity from the bedroom when conditions are humid, but not too hot. These conditions occur especially at night time. So, the bedroom with newly designed temperature and relative humidity with large memory sensor installation could control temperature and relative humidity to keep steady at average ±0.5ºC and relative humidity at average 56.35% RH by dry mode air-conditioning system implementation. It is ideal to maintain relative humidity within 50% – 60 %RH per expectation. However, the newly designed sensor is 39% more expensive than the old newly designed sensor due to more efficiency of newly selected microcontroller unit with a large SRAM impact.

The relative humidity level control methodology within the bedroom by dry mode air-conditioning system depends on many factors such as the positioning of air-conditioning system installation, type of building material (concrete or mirror wall, etc.), external environment surrounding the bedroom, bedroom placement within the building, etc. These factors may affect the room's relative humidity level control results. Thus, designing of an air conditioning system for another room may not be able to follow the same design as this experiment. In the future, the artificial intelligence sensor system (AI) is a future work candidate. An AI system would assess the bedroom environment and takes actions to control relative humidity in varied conditions.

References

Thongkhome P and Veangkum S. (2019). Experimental Studies of Automate Temperature and Relative Humidity Control System Using Drying Mode Air-Conditioning System, The 19th International Conference of Public Health Sciences in Collaboration with the 11th Teikyo-Havard Symposium, 84-85.

Thongkhome P and Veangkum S. (2019). Experimental Studies of Automate Temperature and Relative Humidity Control System to Minimize Adverse Health Effects, International Conference on Advancement in Health Sciences Education and Professions : Synergy and Reform for Better Health , 12.

Holm, D, Engelbrecht, FA (2005). Practical choice of thermal comfort scale and range in naturally ventilated building in south Africa, Journal of the south African institution of civil engineering 47, 9-14.

Baughman, AV, Arens, EA (1996). Indoor humidity and human health-part I: literature review of health effects of humidity-influenced indoor pollutants, ASHRAE Transactions 102, 193-211.

Balaras, CA. Dascalaki, E. Gaglia, A. (2007). HVAC and indoor thermal condition in hospital opearation rooms, Energy and Buildings 39, 454-470.