Project Summary: Room Condition Monitoring System

The propose of the project is to calibrate and integrate the sensors with Arduino coding on the sensor board provided by University of Toronto MIE1050 course. The system consists of temperature and relative humidity sensor, photoresistor, and noise sensor integrated with a ESP32 microcontroller. Readings from sensors are used to determine the corresponding marks. The summation of marks will be used to determine if the room condition is more suitable for studying or resting. Information can be printed on an LCD printing screen. The sensor board will be programmed with Arduino IDE.

Sensor Calibration

To calibrate the temperature and relative humidity sensor (SI7021), a closed small room is set as shown in figure below. An air humidifier and an electric heater fan are used to adjust the temperature and humidity of the room. Readings from an analog thermometer are used as the reference readings.

The temperature of the closed small room is firstly raised to 40 ºC with an electric heater. The heater is then shut, and the temperature is allowed to decrease naturally. The temperature reading on the white digital thermometer and the temperature reading directly returned by the temperature sensor on the sensor board are recorded every 5 to 10 minutes (once the temperature drop is obvious enough comparing to the last reading).

The relative humidity of the room is risen to 70% with an air humidifier and then allowed to naturally decrease. The relative humidity readings from the sensor board and the analog thermometer (blue) are recorded every 10 to 15 minutes (once the humidity drop is obvious enough comparing to the last reading).

The relationship between the sensor and analog thermometer readings is assumed to be linear. Linear regression method is used to determine the linear relationships between sensor reading (T_s, H_s) and thermometer reading (T_c, H_c) are determined as following:

$$T_c = 0.9054T_s - 0.0379$$

$$H_c(\%) = 0.9221H_s(\%) + 3.9858\%$$

To calibrate the light sensor, the reference illuminance of the room is needed. The light sensor is placed to facing a white wall. The camera is placed closely beside the sensor, also facing the wall. An adjustable flashlight with uniform flood light is used to illuminate this wall for a large enough area. The brightness of the flashlight is adjusted between 5 levels. At each level, one photo is taken and 40~80 sensor outputs are recorded. For each level, the aperture, shutter speed and ISO settings are recorded, and the exposure compensation is adjusted in RawTherapee software until the histogram of gray brightness of pixels peak in the center (mode is at half exposure). The reason not to use mean exposure of the whole field is due to vignetting effect of lenses, which lead to faulty exposures in the corners. After collecting illuminance level measurements, it is assumed that the analog reading from the light sensor (L_s) is quadratically correlated with the reference illuminance level (L_c):

$$L_c = 8.585 * 10^{-5} L_s^2 + 26.63$$

The environment noise level is measured with a microphone CMC-9745-44P built-in on the sensor board. The reading is directly requested with Arduino function. Since the noise sensor is too sensitive to environment noise and returns a very small reading in normal environment (40dB to 70dB), the measurement noise could overwhelm the actual noise level reading. The study and rest marks are determined directly from the analogRead() values from the sensor.

Study and Rest Marks

To determine if the room condition is more suitable for studying or resting, two marks are set based on the ideal (recommended) room temperature, humidity, and light conditions for working and sleeping:

Term	Working	Sleeping
Temperature (ºC)	20-26	24.8
Relative Humidity (%)	40-70	64
Illuminance (LUX)	500-1500	<500
Noise (dB)	<70	<40

Four pairs of working and sleeping marks from four sensors will be summed. A total sleeping mark and a total working mark will be generated. The sleeping and working marks have a top limit of 4 (perfect for sleeping or working) and can be negative. If the total working mark is higher and greater than -4, the system will indicate that the current room environment is more suitable for working; if the total sleeping mark is higher and greater than -4, the system will indicate that the current environment is more suitable for sleeping; if both working and sleeping marks are smaller than -4, the system will indicate that the current environment is not suitable for both. To eliminate the measurement noise during data collection for calibration, the microcontroller is programmed to request reading from sensors every one second, collect ten readings and take the average value as the sensor readings for the last 10 seconds. Calibrations are performed based on this 10-second average filtered readings.

Conclusion and Future Works

Overall, the system performs well under normal daily working and resting environments and can give reasonable judgement on the room environment conditions. Future recommendations on improving the system includes adding dangerous gas sensors and dangerous gas alarm, as well as use Wi-Fi and Bluetooth modules built in the microcontroller to connect the system to the cellphone.