System Design:

In this study, indoor air quality is measured by a self-built device which is controlled mainly by two Arduino Boards. The device will measure indoor air pollutants such as fine dust, and other targets like temperature, humidity, and the concentration of carbon monoxide. The device will load the collected data into the processor and provide a comparison of air qualities. Furthermore, as the research does not require real-time communication for data processing, a LAN connection is built between a local computer and the Arduino-based device. After the data is collected and stored in the Arduino, the device will also extract and analyze external data from the U.S. EPA, which represents the outdoor air quality. The visualization and analysis are conducted through the Python library.

The overall system design is shown below in Figure 1.

1. Hardware Architecture

The self-built device includes 2 Arduino Uno Rev3, a PMS 5003 sensor, a DHT 11 sensor, an MQ2 sensor, and an MQ131 sensor. The PMS 5002 sensor is used to detect the concentration of fine dust like PM 2.5; the DHT 11 sensor is mainly for the temperature and humidity measurement, and the MQ2 and MQ3 sensors are both used for gas detection. (The sensor selection criteria consist of sensors that are capable of extracting external air components provided by EPA.)

As Arduino is the most commonly used board for sensor measurement, it is used as the data processor and motherboard. The Arduino board is connected to the local computer to form a basic hardware setting. The specification of the basic components of Arduino is shown in Figure 1.

To measure the concentration of fine dust, a high-precision laser sensor called PMS 5003 is used. The PMS 5003 sensor will detect any particles which may be qualified as PM 2.5 in the air. The detailed information on the dust sensor is shown in Figure 2.

Because the temperature and humidity sensor which is also called DHT 11 sensor requires flowing air to collect data, this sensor is implemented outside of the measuring device. The product specification of the Temperature and humidity sensor are shown in Figure 3.

In the case of the gas sensors, the self-built device applies two sensors. The MQ2 sensors are used to measure Carbon Monoxide (CO), and the MQ131 sensor is used to measure Nitrogen Dioxide (NO) and Ozone (O3). The specification of the two gas sensors is shown in Figures 4 and 5 respectively.

1. Software Architecture

The Software Architecture consists of Node-red, Arduino Integrated Development Environment, and Jupiter Laptop.

1. Node-Red

Node-red is a flow-based development tool for programming hardware devices by wiring them up as part of the Internet of Things. All processes are aggregated together in the flow, and the feature of Node-Red allows the developer to grasp the data flow easily. The core of Node-Red is Node.js, which is a JavaScript runtime, thus it can be used to develop JavaScript functions. Furthermore, Node-Red also uses JSON to describe its metadata but not XML, which will not make the metadata to be a huge pile of the hard-to-read block. Finally, Node-Red also allows the developer to implement functionality by wiring together flows of data between nodes using a browser.

1. Arduino Integrated Development Environment

The Arduino Integrated Development Environment or Arduino Software (IDE) is a kind of environment facing programmers. It contains a text editor for writing codes, a message area, a text console. And a toolbar with buttons to provide common functions and a series of lists. The IDE can connect to the Arduino hardware to upload or implement programs and scripts, and communicate with the physical components.

1. Jupyter Notebook

Jupyter is an open-source based web application. In addition to Python, it also provides a development environment that supports 40 programming languages.

1. Methodology

In this study, the indoor air quality measurements were conducted at some general indoor buildings on the campus of Purdue University from February 14 to 18, 2022 to measure indoor air in the United States. There was a total of four buildings measured, including a dining court called Earhearts, a Gym called Corec, and the WALC building. Schedule data was measured for 1 hour a day for each indoor place, and 120 samples were collected by checking each sensor after starting it for 30 seconds. 120 samples per day were measured for a total of 5 days to collect 600 data per pollutant. Indoor air measurement items include carbon monoxide (CO), lead (Pb), NO2, Ozone, PM10, PM2.5, and SO2, which can be measured by a device sensor included in the U.S. Environmental Protection Agency (EPA) as components of outdoor air quality, and general temperature and humidity. The pollutant standard (level) is ug/m3 for fine dust and ppm for the other remaining substances based on the figures provided by EPA. In addition, data from February 2021 in Indianapolis was used among outdoor data provided by the U.S. Environmental Protection Agency to increase the accuracy of comparison between directly measured data and public data

At the time of data collection, a table was designed based on each place [fig.2], and the data collected here were extracted in the form of CSV files. As a database, My SQL was used as a relational database. The Jupiter laptop was used as a program to analyze CSV files, the Pandas data analysis library provided by Python for data analysis, and the matplotlib visualization library for data visualization.