# Visualization of the Airborne Dust Concentration on the Building Floor Plans

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**ABSTRACT**

**Indoor airborne dust concentration is one of the most adverse factors for human health. Especially, inhalable fine particles under 2.5micrometres in diameter (PM2.5) easily permeate into human body causing serious respiratory diseases. The problem is that the air pollutions are hard to be detected with human sense organs alone. Therefore, the development of an effective method to figure out the indoor air quality should be combined with other political approach. Moreover, measuring wide range of indoor environment continuously became affordable because of diverse sensors become downsized and low-priced. In this regards, as the way to collect and intuitively visualize the indoor dust concentration data, this paper proposes an integrated approach to the visualization of indoor dust concentration on the building floor plans. The entire system consists of four major stages: 1) Dust concentration measurement, 2) Data processing, 3) Layer generation and 4) Data mapping. The sensor toolkit was implemented with Arduino Uno Board and Optical dust sensor (GP2Y1010AU0F), which is able to measure fine particles over 0.8um at maximum. In short, this paper proposes a way to visualize of indoor dust density.**

**Keywords – Dust concentration, Fine particle, Data visualization, Air quality, Sensor**

## 1 Introduction

Managing indoor air quality is one of the important requirements for maintaining our daily life healthy [1]. Especially the adverse effects of inhalable fine particle are very hazardous in both case of short-term and long-term exposure [2]. But the analysis of the indoor airborne dust or any idea for reduction of indoor air pollution is not in the scope of this paper.

The main purpose of this paper is to suggest an approach to visualize the indoor concentration data with concise sensor network. It became possible due to the advent of affordable sensors and advanced network technology [3]. The overall system and approach is based on the preceding research [4]. In the former study, we developed a mechanism for visualizing the temperature change distribution of a space on Rhino-grasshopper environment. In this paper, we implement the visualization system on the Processing environment.

## 2 Background

According to the size of the particle, fine particle pollution is classified into PM10 and PM2.5. PM10 indicates relatively coarse particle size between 2.5 and 10 micrometres (µm) in diameter and PM2.5 indicates particles less than 2.5 micrometres. The size of the particle is important because smaller particles are more deadly to human body [5]. Especially in indoor environment, the importance of air quality becomes more significant since it is more possible to be exposed to particle pollution for long-term [6].

With the growing of interest on seriousness of fine particle, diverse investigations and efforts about small-particle pollution are being accelerated. Especially, regulatory standards on fine particles under PM2.5 are being intensified internationally. World Health Organizations (WHO), proposed a recommended annual indoor average concentration of PM10 and PM2.5 in Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide(2005) [7]. The report suggests 10µg/m^3 of PM2.5 as annual mean and 25µg/m^3 of PM10 as 24-hour mean which is applicable to both indoor and outdoor spaces.

The problem is that it is difficult to detect air pollutions with human sensory organs alone. Therefore, not only for the political efforts and academic analysis for air pollution management, it is more important for the occupants to aware about their own indoor environment. In general, indoor air condition is assumed based on the outside air pollution index since there is no way to figure out the local indoor air condition. Even if it is available to use existing indoor air quality sensors, they generally report only numeric data of current air condition [8].

In the research of Sunyoung Kim & Eric Paulos, they developed "inAir" system, which is a tool to measure, draw graph and share their local indoor air quality. According to their research, comparing the visualized data of local indoor air quality with other places raises the awareness about the air pollution and motivates people to make positive change toward their air quality [8].

In this regards, this paper aims to propose a visualization system for indoor dust concentration, which is able to visualize the indoor air quality of plural spaces. By providing the dust concentration data as a comparable visual information, it is possible to understand the relative state of air quality. In addition, since the visualization output is represented on the floor plan of the target space, it reveals the relationship between the air condition and architectural environment.

## 3 Visualization Process

The visualization system requires two data type; 1) the environmental data measured by sensors and 2) the spatial data of target indoor space from building model. Each data type is mapped into a layer and combined at the end of the visualization process.

Over the whole process for data visualization, a series of procedures are needed in order to generate input data. For the first, the particle concentration is measured by installed sensor network. Each time the sensors operate, three types of raw data are collected including particle concentration degree, measurement time and sensor location. In sequence, the collected data are loaded to the Processing platform to be processed into input data for visualization. After calibrating the measured value to standard particle concentration unit, then the air condition data is processed into several parameters to be represented as a part of visual elements such as the colour or size of geometric shape representing the environmental condition at each space. The sensor location data is mapped with the coordinates of the corresponding geometric shape. In case of measured time data, it is used to retrieve and generate statistically significant data as an index for input data.

The spatial data of target indoor space such as 2D floor plan or 3D building geometry is required as the basis of analysis. It is directly exported from the building model. According to the compatibility between the spatial data with visualization system and the method, the spatial data have to be exported to an appropriate form.

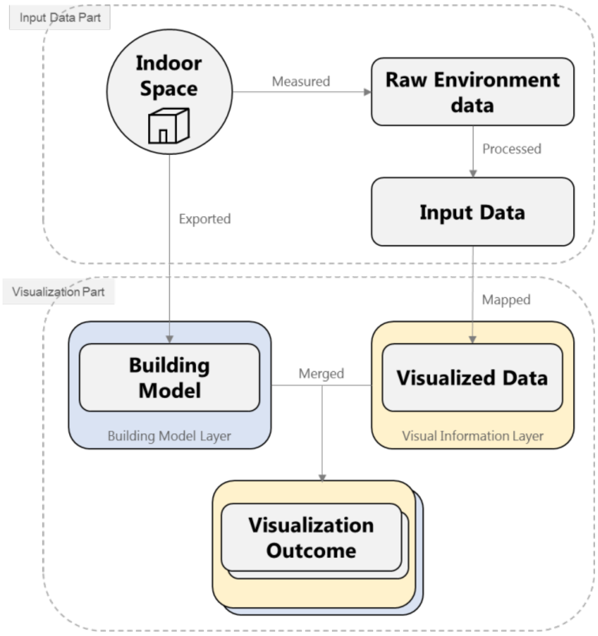


Figure 1. Overview of visualization process

## 4 Implementation of Visualization

This chapter describes the data processing methods and apparatuses at each stage in detail. The system consists of two main parts: 1) Input Data Part and 2) Visualization Part. These are subdivided into 4 stages: 1) Dust Concentration Measurement, 2) Data Processing, 3) Layer Generation and 4) Data Mapping for Visualization. The processes in Input Data Part are operated mainly based on Arduino Environment. Arduino is a microcontroller board which is able to make devices that interact with environment using diverse electronic sensors and actuators. The overall processes in Visualization Part are operated mainly based on the Processing platform. Processing is an open source integrated development environment (IDE) with own language for diverse implementation of media art work or visual design.

### 4.1 Dust Concentration Measurement

In this research, Arduino Uno Board and Sharp Optical Dust Sensor (GP2Y1010AU0F) are used as the toolkit to measure the air condition. Since it is programmed with Arduino language based on the Processing language, it is easily compatible with the Processing environment.

The sensor detects the reflected light of dust in the air and is capable to measure up to 0.8 μm in particle size. Therefore, it is effective to detect very fine particle like the cigarette smoke [9].

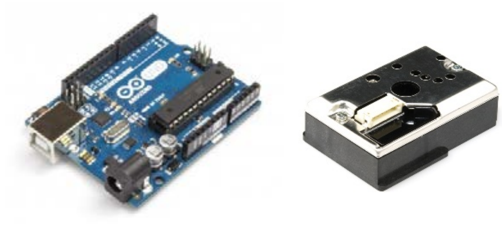

Figure 2. Arduino Uno Board(left) and Sharp Optical Dust Sensor - GP2Y1010AU0F(right)

Figure 4 shows a snippet of Arduino language that operates the sensor in 1 second delay. The measured data are transmitted to connected serial port. In order to collect the transmitted signal and make dataset, PLX-DAQ (Parallax Data Acquisition tool) which is an Excel plug-in for data collection exported from Arduino into Excel sheet.

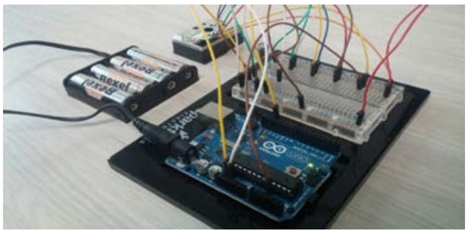

Figure 3. A single set of sensor toolkit

There are three types of data to be collected: dust concentration, sensor operation time and sensor location. Dust concentration is obtained in the form of digital signal, which is an integer value between 0 and 1023. The sensor operation time is also obtained by the sensor. It can be controlled in seconds by Arduino code. The measured time data is used to retrieve and generate statistically significant data such as the change or average value of dust concentration. In case the system needs the exact sensor location, the location data can be gained by separate IPS (Indoor Positioning System) module and the measured data can be acquired by network module such as Zigbee for Arduino Board. But since the visualization system of this research does not need the exact location of sensor, the sensor locations is designated manually.

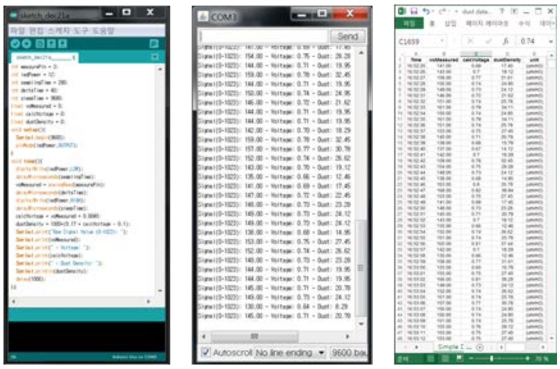

Figure 4. Arduino code (left), Input signal (center) and Collected data (right)

## 4.2 Data Processing

In data processing stage, the dust concentration data collected from the previous stage is converted into a parameter for visualization element. The data is processed through three steps: 1) the signal value is converted to proper dust concentration unit, 2) the raw data is imported on the Processing module, which is the visualization platform of the system and 3) the combination of the imported data generates statistically significant information to be visualized.

For the first, since the measured value expresses the dust concentration in the form of signal value between 0 and 1023, it has to be translated to µg/^m3 unit which is the standard unit for fine particle concentration value. Figure 5 shows the output voltage versus dust density ratio from sensor datasheet [9]. Considering the relation between the measured signal and output voltage, the conversion ratio between measured signal and dust concentration can be calculated as a line equation as follows: [10]

$$Dust\ density(\mu g/^{m3}) = 0.833 * Input\ signal - 100 \quad (1)$$

The data conversion operation can be made both on Arduino or Processing environment. In other words the raw data can be processed either before or after the data collection in case of a simple translation.

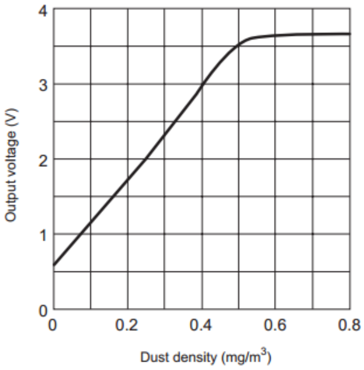


Figure 5. Dust density vs Output voltage ratio

The raw data collected in a csv file is imported into the Processing project data. By referring to the coordinates of excel table, it is possible to retrieve the data at a particular part. The Figure 6 shows a part of the Processing code that loads the dataset into the Processing environment and defines each dataset of a sensor into a parameter.

```
table = loadTable("dust.csv", "header");
println(table.getRowCount() + "total rows in table");
for (TableRow row : table.rows()) {
  String time = row.getString("time");
  int analog = row.getInt("analog");
}



.........



float lectureA = table.getFloat(time,3);
float jang = table.getFloat(time,4);
float janglab = table.getFloat(time,5);
float BIMlab = table.getFloat(time,6);
float CAD = table.getFloat(time,7);
float studyroom = table.getFloat(time,8);
float equipment = table.getFloat(time,9);
float lectureB = table.getFloat(time,10);
float hwang = table.getFloat(time,11);
float hwanglab = table.getFloat(time,12);
float shin = table.getFloat(time,13);
float lee = table.getFloat(time,14);
float ted = table.getFloat(time,15);
```

Figure 6. Importing data table and reading data

After importing statistic information such as average value, maximum or minimum value and intensity of variation can be extracted by loaded data set. Although the average value for 24-hour mean is the adequate information to be extracted according to WHO guidelines, the average dust concentration data is processed into average value for a minute because the analysis or air quality itself is not in the scope of this paper.

## 4.3 Layer Generation

In order to represent the visualization output on the Processing screen, it is required to generate and merge two layers: Visual information layer and building model layer. The former is mapped with the processed input data and appears in the form of graphic information. The latter is mapped with building floor plan of target indoor space, which is the basis of visual information.

In order to generate the building model layer, the boundary of the layer needs to be generated. The size and proportion of the layer has to be decided considering the shape and scale of the floor plan. The building floor plan is mapped into the generated layer. Since the DWG file format is not compatible with the Processing environment, the floor plan is loaded as JPG image and mapped with the layer. When the two layers are combined, the building floor plan becomes an important element for analysis on the relationship between the architectural environment and the air quality.

The visual information layer is composed of a set of box geometries. Each box represents the state of air quality on each room with the height, colours and transparency. The box geometries of visual information layer as shown in the Figure 7 have plat square form since the boxes have not given with the height parameter, which is going to be mapped with the input data.

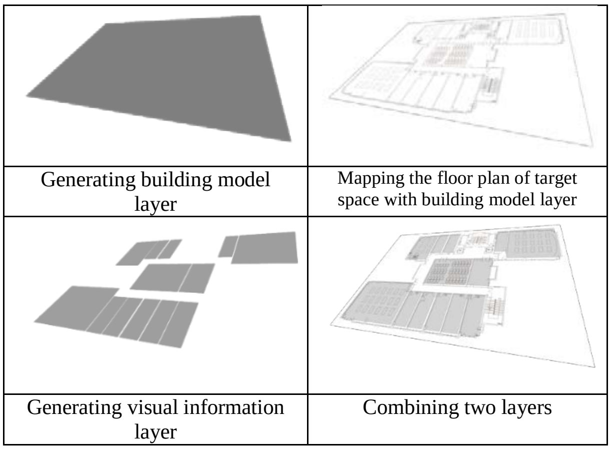


Figure 7. Generating and merging two layers. The boxes in visual information layers are manually positioned according to the building model layer.

## 4.4 Data Mapping

In the data mapping stage, the processed input data is finally converted to a visual information. For this, the data value defined at data process stage is mapped into the parameter of visual elements. Since the purpose of the visualization is comparing the relative degree of dust concentration at plural spaces, the environmental data is expressed as the size and colour of geometry. As defined in data process stage, the input data is the average dust concentration value for a minute from each room. The minimum and maximum value of the input data is mapped to the range of parameter to be visualized. The range of input data from $2\mu g/m^3$ to $80\mu g/m^3$ and that is mapped to the height of the box geometry between 1 and 100 pixels. Moreover, In order to represent the dust density with the colour and transparency of box geometry, the input data is also mapped with the RGB colour and transparency code. The input value is represented as text object too on the top of box. Likewise, as input value becomes higher, the transparency of the text becomes lower.

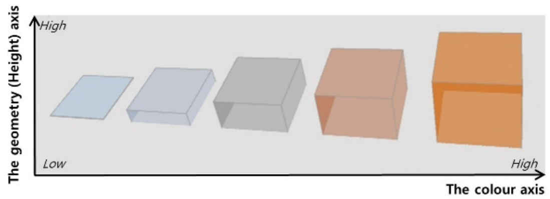


Figure 8. Visualized output from minimum value to maximum value

## 5 Demonstration

The demonstration was conducted on the 5th floor of a building in Hanyang University, Korea. The target spaces include one library, one equipment room, three lecture room and eight offices. Since the air condition of corridor, stair hall and rest room is hard to be directly compared with each rooms, they were excluded from demonstration. The dust concentration of each spaces was measured in an afternoon for 30 minutes in a second delay and the input data was processed as the average value for one minute.

Figure 10 is the final visualization results in the Processing screen. As the parameters defined in Data mapping stage, the dust concentration has expressed as text and the height, colour and transparency of box geometry.

At the two rooms highlighted with red circle in Figure 9, the average dust concentration was far higher than other spaces. The highest dust density value represented with orange coloured box geometry was $34.44\ \mu g/m^3$, which is far higher than the recommended average dust density value for a day proposed by WHO guideline. The reason the rooms has high dust concentration is assumed that the rooms are bordering the driveway and many computers are installed.

Figure 9. Visualization result in vertical view. The rooms with high dust concentration valuse is highlighted with red circle.

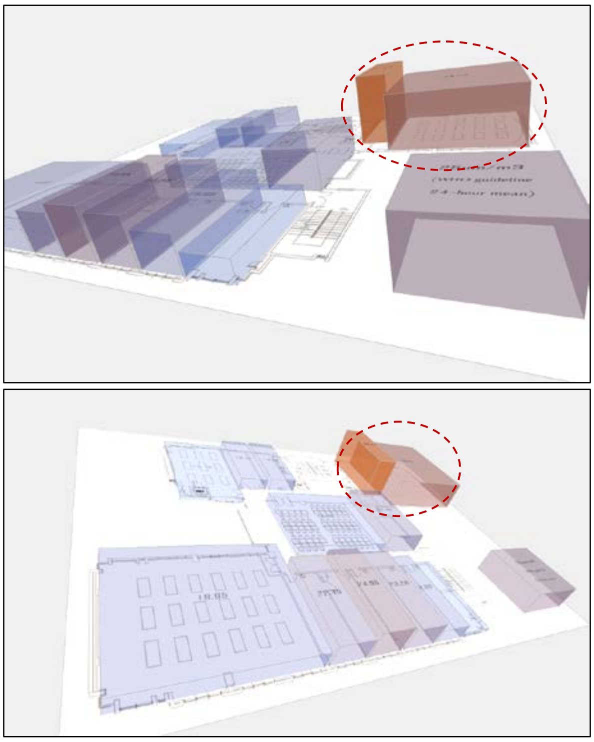

Figure 10. Visualization result in perspective view

## 6 Summary

The entire system can be divided into two major parts:

Input data part and Visualization part. The processes in input data part is mainly conducted on Arduino environment. This part includes from sensor operation to data collection. The processes in visualization part is mainly made on the Processing environment. It includes the processes from data import and processing to data mapping for visualization outcome.

This paper proposes an approach to visualize the indoor dust concentration on floor plan in compare with plural spaces with a demonstration. The main purpose of the study is to represent the air condition data in a more intuitive and analysable way. Especially, by showing the data compared with other spaces, we made it easier to aware the relative air condition to others, with extensive data and more elaborated building model, it would be possible to help the analysis of the relation between the building environment and air pollution. In addition, considering the expandability of the mechanism, it is expected to develop various sensor application, visualization mechanism, IPS and sensor network system in further studies

## 7 Acknowledgment

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## References

[1] Hee-geon Park, Myeong-jin Ko and Yong-shik Kim. Measurement and Assessment of Indoor Air Quality in Newly built University Buildings, *Journal of the Korean society of living environmental system*, pages 339–362,

[2] Valavanidis A, Fiotakis K and Vlachogianni T. Airborne Particulate Matter and Human Health: Toxicological Assessment and Importance of Size and Composition of Particles for Oxidative Damage and Carcinogenic Mechanisms, *Journal of Environmental Science and Health*, pages 339-362, C 26:1 -24

[3] Uglješa Z. Jovanović1, Igor D. Jovanović2, Andrija Z. Petrušić, Zoran M. Petrušić4 and Dragan D. Mančić. Low-cost Wireless Dust Monitoring System, In Proceedings of Telecommunication in Modern Satellite, Cable and Broadcasting Services (TELSIKS) 11th International Conference, 2013

[4] M Shin, S Lee, H Lee and J-K Lee, Sensing the room: an integrated implementation process to visualize indoor temperature data on floor plans, *Visualization in Engineering*, 2:10 DOI: 10.1186/s40327-014-0010-2, 2014

[5] US Environmental Protection Agency. Particulate Matter (PM) Research, http://www.epa.gov/airscience/air-particulatematter.htm, Accessed: 30/01/2015

[6] Li-Tianhua, Wu Ying. Design of Indoor Dust Concentration Monitor based on Light Scattering Detection Method, *Scientific research and essays*, Vol.9(9), pp. 321 - 324, 2014

[7] World Health Organization (WHO). Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, 2005

[8] Sunyoung Kim, Eric Paulos. inAir: Sharing Indoor Air Quality Measurements and Visualizations, In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1861–1870, 2010

[9] Sparkfun.com, Specification sheet Sharp GP2Y1010AU0F, https://www.sparkfun.com/datasheets/Sensors/gp2y1010au_e.pdf, Accessed: 30/01/2015

[10] Chris Nafis, Monitoring your Air Quality, http://www.howmuchsnow.com/arduino/airquality, Accessed: 30/01/2015