The Plantower PMS5003 and PMS7003 Air Quality Sensor experiment

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Plantower PMS 5003 and PMS 7003 Sensor

The PMS 7003 and PMS 5003 sensors are the 7th resp 5th generation of the PMS*x*003 series developed by Plantower (chinese name 攀藤).

PMS5003

Experiment Setup

This experimentation is dedicated to our colleagues at Haier, IBM and Google.

For this experiment, 3 PMS 7003 and 3 PMS 5003 are co-located together. The objective is to understand the accuracy of individual sensor readings, and potential level of error induced by the lack of efficient calibration of low-cost sensors .

PMS7003

For each sensor (PMS5003 and PMS7003), there are 3 sensors (identified as PMSx003 #1, #2 and #3) running in alternation over a period of 3 minute. For each minute, only the last 30 seconds data is collected, as the first 30 seconds as kept to let the sensor stabilize its output.

There is additional PMS5003 sensor (number #4): It is a used *(old)* sensors which has been

running in continuous mode for several months outdoor. The objective for this sensor is to understand if the accuracy decreases with the age (during to the laser or fan wearing off).

Specification sheets: PMS5003.pdf and PMS7003.pdf.

Note that the PMS_x data from the Sensor comes in two flavors: '标准颗粒物' (Standard Particles or CF-1, bytes 4-9) and '大气环境下' (Atmospheric Environment, bytes 10-15). It is the second one which we use for this experiments (Thanks to Bart for the clarification).

Sensor tear-down

The following pictures are taken from a PMS5003 running for several months outdoor in continous mode.

Accumulated Dust
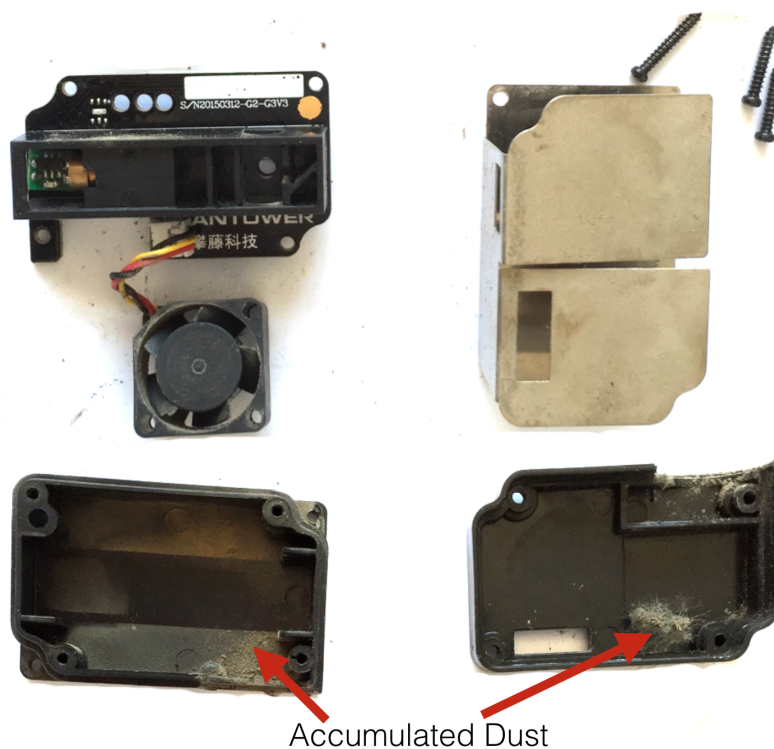
The good news is that Plantower managed to do a pretty good mechanical design which prevents dust accumulation on the front-side of the PCB (see image A on the right), where laser and

No dust accumulation

Dust over all the PCB

diode are mounted. Compared to the dust accumulation on the Dylos, that guarantees a much better lifetime and data accuracy over time.

In terms of electrical and electronic components, the PMS5003 is not quite different from the initial PMS1003 desing. The CPU is still a Cypress CY8C4245, which a combined ARM Cortex-M0 running at 48Mhz with dedicated ADC, used to sample the output from the diode.

Real-time data

`db` stands for *dust bin* and is measured in counts per minute. For instance, `db2.5-um` represents the count of particles with an aerodynamic diameter below 2.5 µm;

Time series for Meteorological Conditions

Meteorological conditions, and especially the Relative Humidity (RH) is needed as high RH might have a direct impact on the size of the particle size detected by the laser. For BAM sensors, there is actually a requirement for constant humidity.

Above graph is based on CWOP station EW2754. Below table is based on the real-time readings from our GAIA A12 station

Time series for Particulate Matter

Note that the first 3 time-series graphs are showing the values using AQI (and not raw mg/m3). The AQI is based on the US EPA breakpoints. For PM_1, the $PM_{2.5}$ breakpoints are used.

For the particulate matter graphs, the reference BAM measurements from the neighbor stations are shown, but not taken into account for the deviation plot ~ the aim of this experiments is to understand the deviation in between sensors of the same type (eg PMS) and not in between sensors using different technologies (eg Laser Counter vs Beta Attenuation).

The deviation plots below each time-series is computed as the difference between the minimum (in blue) resp. maximum (in red) value and the average reading for each 5 minute period block. The X axis is showing the average value, and the Y axis the difference between min/max and average. For the first 3 time-series graphs, the difference is expressed in AQI: This way, it is easy to asses the potential error in AQI value of those low-cost sensors.

Comparison between Std. Particle (标准颗粒物) and Std. Atmosphere (大气环境下)

CF1 refers to Std. Particle (标准颗粒物). SAT refers to Std. Atmosphere (大气环境下).

The graphs below shows the correlation for the CF1 (X, absyss) and the ratio CF1/SAT (Y, ordinate), for the $PM_{2.5}$ and PM_{10} data.

The almost too perfect correlation between approx. 30 mg to 100 mg for PM2.5 / PMS5003, (40mg to 150 for PM10) does not sound too scientific...

```
                cf1<30 ⇒ sat = cf1
              cf1>100 ⇒ sat = cf1 * 2/3
   cf1 in ∈ [30;100] ⇒ sat = 30 + cf1 * (cf1-30)/70 * 2/3
```

Note: Thanks to Bart for the comment on `CF1>30 ⇒ SAT < CF1`
The formula has been updated with correct ratio (2/3)

One interesting question is whether is CF-1/SAT ratio is part of the calibration process done by Plantower; At least, for PM2.5 the upper threshold for PMS7003 and PMS5003 are different (85 for the first, and 100 for the second). When sufficient data is available, this page will be updated with the answer...

Correlation between PM10 and PM2.5

Refering to the experiment on PM_{10} vs $PM_{2.5}$, the question is weather the PMS sensor is able to correctly detect the particules. The graph below show the correlation between PM_{10} vs $PM_{2.5}$ CF-1 readings for the past 10 days.

For now, the correlation seems perfectly linear, but as soon as the next PM_{10} pollution event comes, the graph will be able to confirm the efficiency of bin size detection.

Moreover, one interesting pattern to check for is the non-linear curve, which can be seen on the Dylos sensor. This curved pattern is due to the sensor not beeing able to properly detect the different particles bins, caused by a too high number of particles 'obstructing' the diode. For now, the Air Pollution is too low to detect this phenomenon, but as soon as winter arrives, the data will confirm the existence of this pattern or not.

Time series for Particulate Matter (Indoor setup)

There are 2 additonal indoor PMS5003 sensors:
The graphs below are expressed in AQI units.
And this is for the meteorological indoor sensor

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About the Air Quality and Pollution Measurement:

About the Air Quality Levels

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially

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AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
			children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

To know more about Air Quality and Pollution, check the wikipedia Air Quality topic or the airnow guide to Air Quality and Your Health.

For very useful health advices of Beijing Doctor Richard Saint Cyr MD, check www.myhealthbeijing.com blog.