The weather station project (Level 4)

Worksheet for students

Team:.....

Aim: Interpretation of collected data

What can be a source of inaccuracy of the measurement? Discuss with your team.

What uncertainty is? Search for information online and write your answers below.

What is a type A and type B evaluation of uncertainty? Search for information online and write your answers below.

How does the uncertainty can be reduced? Discuss with your team.

Time for data analysis!

Run your code from previous levels and wait few minutes to collect the data. Open serial monitor to observe values. If you have enough data (minimum 20 measurements of temperature, pressure, humidity and dust concentration separately), select all data and copy it to chosen spreadsheet.

The temperature, pressure, humidity and dust concentration values vary. Therefore the question arises what are the real values of temperature, pressure, humidity and dust concentration? During this level, you gain possibility to answer to these questions by repeating the data analysis process in the same way as scientists do.

The analysis of data consists of the following steps:

1. Calculation of the average value of chosen quantities by using equation:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i, \tag{1}$$

where: x_i is a single measured value, N is a number of measurements.

Example:

- Measured temperature points: 24.3, 24.9, 23.5, 24.0, 24.6,
- Sum of points is: $24.3 + 24.9 + 23.5 + 24.0 + 24.6 = 121.3$,
- The average value is: $\bar{x} = 121.3/5 = 24.26$

2. Calculation of uncertainty (type A) according to the statistical analysis:

$$u_x(type\ A) = \frac{s_x}{\sqrt{N}} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N(N-1)}} \tag{2}$$

where: s_x is a sample standard deviation.

If you have much data and plot histogram of this data, you will receive similar plot as in Fig. 1. A sample standard deviation indicates area around the average value, where about 68% of collected values will be located.

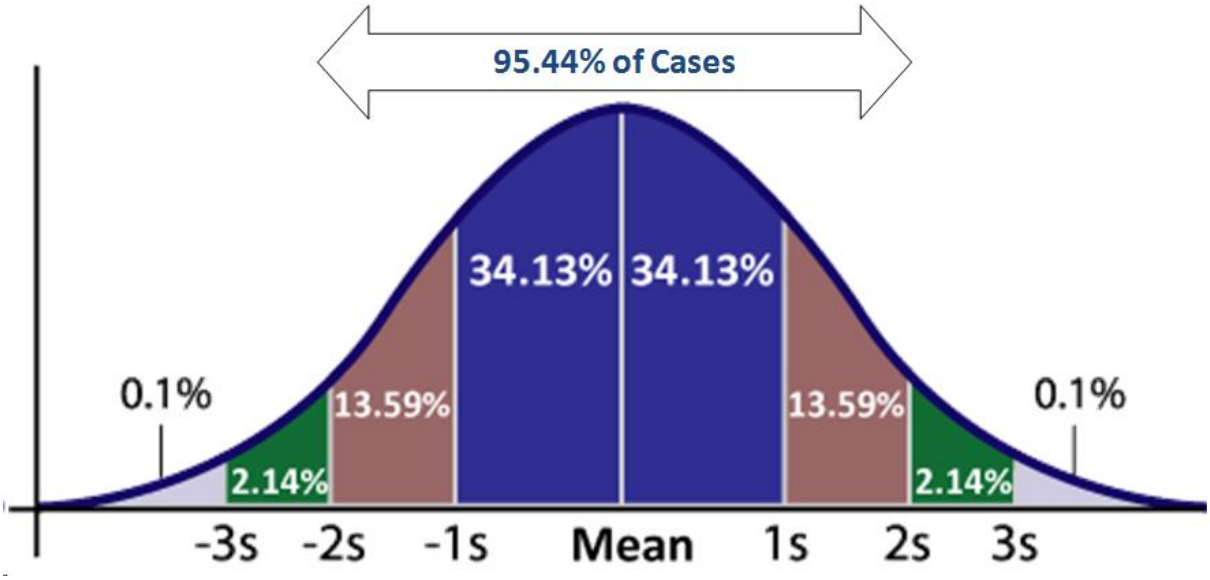

Figure 1: The interpretation of a sample standard deviation.

Example:

- Measured temperature points: 24.3, 24.9, 23.5, 24.0, 24.6,
- The average value is: $\bar{x} = 24.26$,
- $\sum_{i=1}^{N}(x_i - \bar{x})^2 = (24.3 - 24.26)^2 + (24.9 - 24.26)^2 + (23.5 - 24.26)^2 + (24.0 - 24.26)^2 + (24.6 - 24.26)^2 = 1.17$
- Statistical uncertainty (type A) is: $u_x(type\ A) = \sqrt{\frac{1.17}{5\cdot(5-1)}} = 0.24$

3. Calculation of uncertainty (type B) related to other sources like resolution of the device, error of the value readout etc. This uncertainty is also called systematic uncertainty:

$$u_x(type\ B) = \frac{\Delta x}{\sqrt{3}}, \tag{3}$$

where: Δx is a boundary uncertainty e.g. accuracy of device usually read from the sensor documentation. The accuracies of BME280 sensor are given in Table 1.

	Accuracy
Temperature	±1.25 C
Pressure	±1.0 hPa
Humidity	±3.0 %

Table 1: The accuracies of quantities measured by BME280 sensor.

Example:

- Measured temperature points: 24.3, 24.9, 23.5, 24.0, 24.6,
- The average value is: $\bar{x} = 24.26$,
- Statistical uncertainty (type A) is: $u_x(type\ A) = 0.24$
- Systematic uncertainty (type B) is: $u_x(type\ B) = 1.25/\sqrt{3} = 0.72$,

4. Calculation of the total uncertainty:

$$u_x = \sqrt{(u_x(type\ A))^2 + (u_x(type\ B))^2}. \tag{4}$$

Example:

- Measured temperature points: 24.3, 24.9, 23.5, 24.0, 24.6,
- Statistical uncertainty (type A) is: $u_x(type\ A) = 0.24$
- Systematic uncertainty (type B) is: $u_x(type\ B) = 0.72$,
- Total uncertainty: $u_x = \sqrt{0.24^2 + 0.72^2} = 0.76$
- The measured temperature is: $T = 24.6 \pm 0.24 \pm 0.72^oC$ or $T = 24.6 \pm 0.76^oC$.

Calculate temperature, pressure, humidity, dust concentration real values with uncertainties according to the above instructions. Put your results here.

ROBOSCIENTISTS PROJECT

Motivating secondary school students towards STEM careers through robotic artefact making

Erasmus+ KA2 2018-1PL01-KA201-051129

Creator
Angelika Tefelska (WUT)

Declaration
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