Technical Manual
Smell Board

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1.   Overview

The Smell Board is an electronic nose device and a developer kit. It is suitable for testing and exploring different smell-related applications in the fields of product quality, safety & security, life & care, air quality, and many others. Smell Board has four multichannel Smell iX16 detector chips based on nanomaterials. Interaction with different gas molecules changes the resistance of each channel in a different way. For every smell, i.e. for every gas or gas mixture, Smell Board measures a specific pattern, a digital smell fingerprint. These patterns are processed and then used for real-time smell recognition. Onboard machine learning algorithms enable the module to classify the detected odors and output them to the user via UART or SPI. For this, use case specific ML model must be created and installed on the microcontroller. The pre-installed ML model has a limited functionality of recognition of H_2S and NH_3 gases (low concentrations in air). Smell Board can be connected to a PC via USB-UART-Converter and can be operated with Smell Annotator software.

WARNING
Usage limitations:
- not for person safety applications
- not water resistant, should not be used in water or other liquids
- not for harsh or explosive gas conditions
- these resources are intended for skilled developers

ATTENTION
OBSERVE PRECAUTIONS
FOR HANDLING

ELECTROSTATIC
SENSITIVE
DEVICES

Note: data and description in this document are subject to change without notice. Product photo and pictures may differ from real product appearance.

2.   Smell Board

2.1.   Scope of delivery

- Smell Board (Main Board, Sensor Board)
- USB-UART-Converter with Connector cable to Main Board
- 2 x dual row pin header RM 2,54
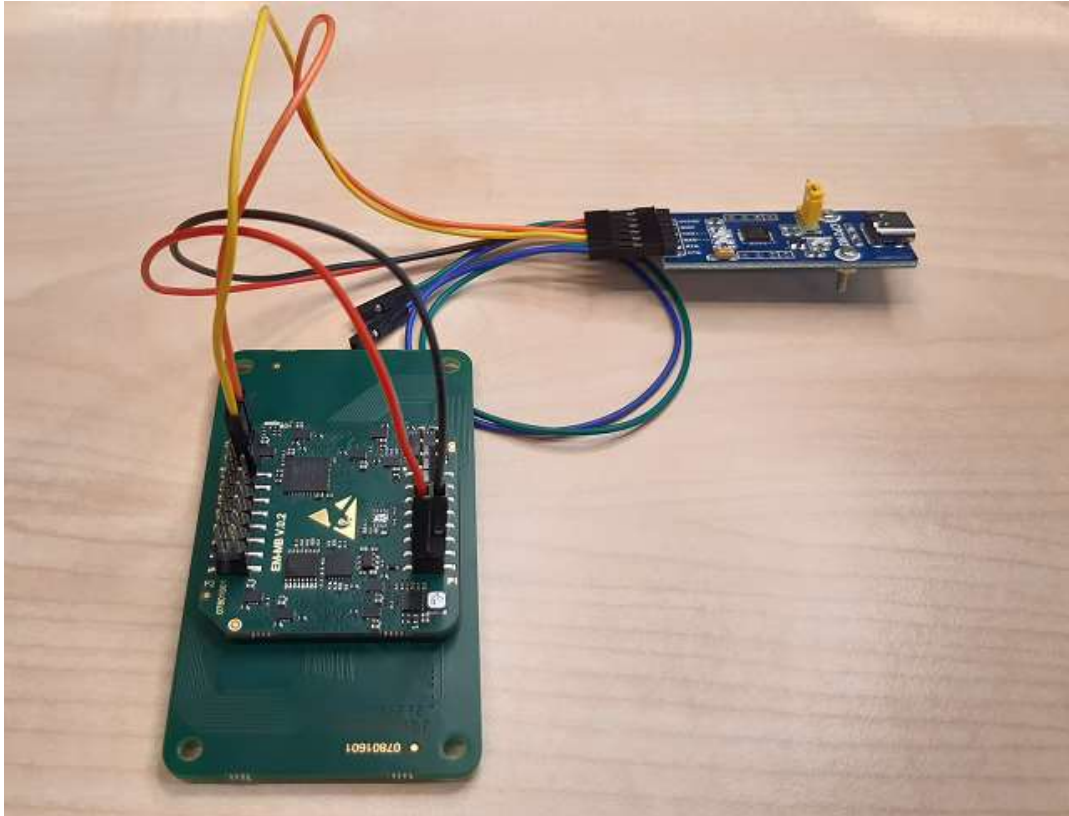
2.2.   Before you start

Before the first measurement, it is important to store the sensor board unpacked for one day. The sensors must adapt to the environment. It is also recommended that if the sensor board is stored in a box, it should be left one day to adapt to the new environment.

IMPORTANT: Please do not touch the detectors on the Sensor Board. They are very sensitive and should therefore be treated with care to prevent damages.

2.3.   How to connect the device?

Step 1 – Take the USB-UART-Converter.

Step 2 – Connect the cable to the Converter PCB.

Step 3 – Connect the cable to the Main Board. The cut edge should be in front of you on the left for connecting VIN and GND. For connecting RX and TX rotate it by 90°, so the cut edge is on the right.

- Red is VIN
- Black is GND
- Orange is TX on USB-Adapter connect to RX on Main Board
- Yellow is RX on USB-Adapter connect to TX on Main Board

The Pinout of the USB-UART-Converter is also written on the PCB and for the Pinout of the Main Board see 2.4 Pinout.
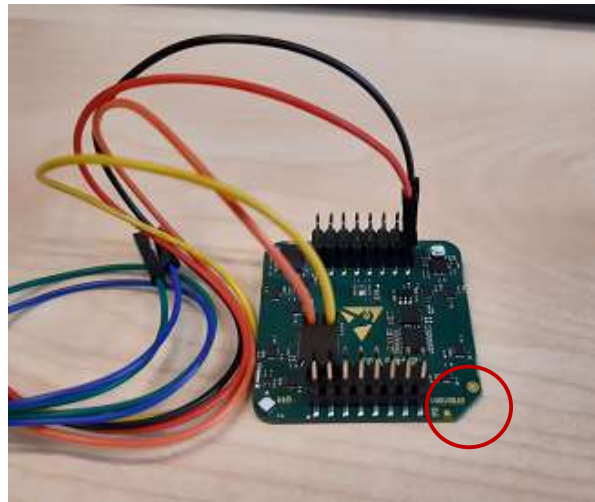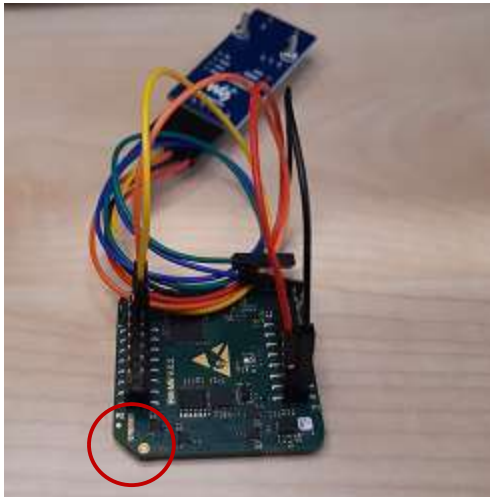
Step 4 – (If the Sensor Board is not connected to the Main Board) Pick the Sensor Board and look for the marking on the bottom side or at the resistors. Be careful with the Detector and please do not touch them.

Step 5 – Place the Main Board on the Sensor Board. With the cut edge on the marking on the Sensor Board.
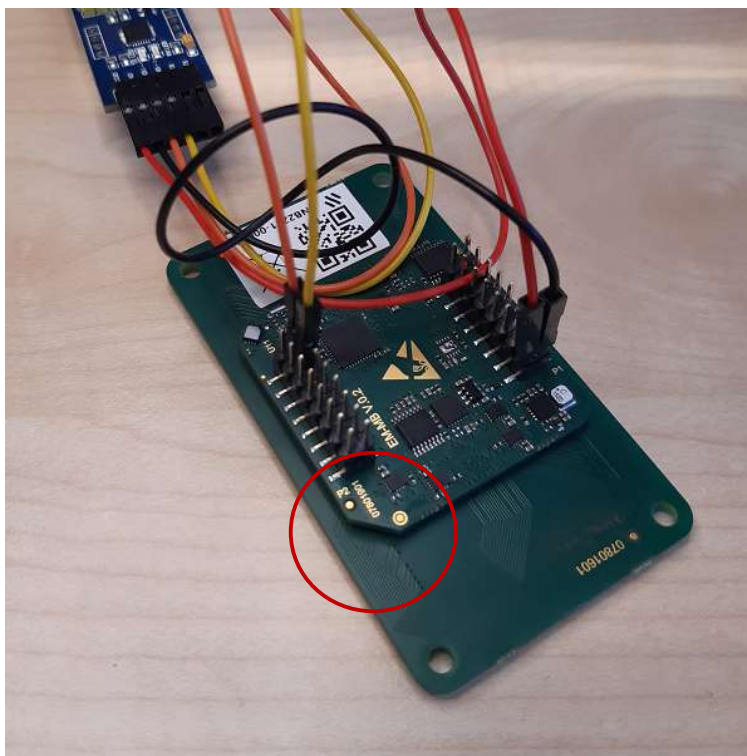
Step 6 – The Smell Board is now ready for measurements. If you connect the Smell Board with a USB-C-Cable to your PC it will automatically start. If everything is connected correct a green LED flashes every 5 seconds. If there is anything wrong, for example if the Sensor Board is not properly connected, the LED will flash in red. How to take a Measurement see 3 Smell Annotator. If you want to configure the data output or the LED configuration have a look at 2.5.5 Error messages

Error message	Description
start;Bad connection to functionalization 1 (P1) 2 (P1) 5 (P2) 6 (P2)	Resistance values of functionalization 1 and 2 from detector 1 in socket P1 and functionalization 5 and 6 of detector 2 in socket P2 got to high resistance values. Repositioning of the detector may help.
start;Sensor Board not inserted\n	All resistance values at the sensor board got to help values. Please check connection between sensor board and main board.
start;Error init LMP\n	LMP91000 (AFE) is not replying. Hardware error.
start;Error init ADC\n	ADC is not replying. Hardware error.
start;Error init SHT\n	Temperature- and humidity-sensor (SHT) is not replying. Hardware error.
start;Error calibration\n	Calibration of AFE and ADC failed.

Configure the Smell Board.

2.4. Pinout

P1 and P2 are dual socket header connectors from Würth (WUERTH 610016243021) with RM 2,54.
Pin 1 is marked with the black point in the picture.
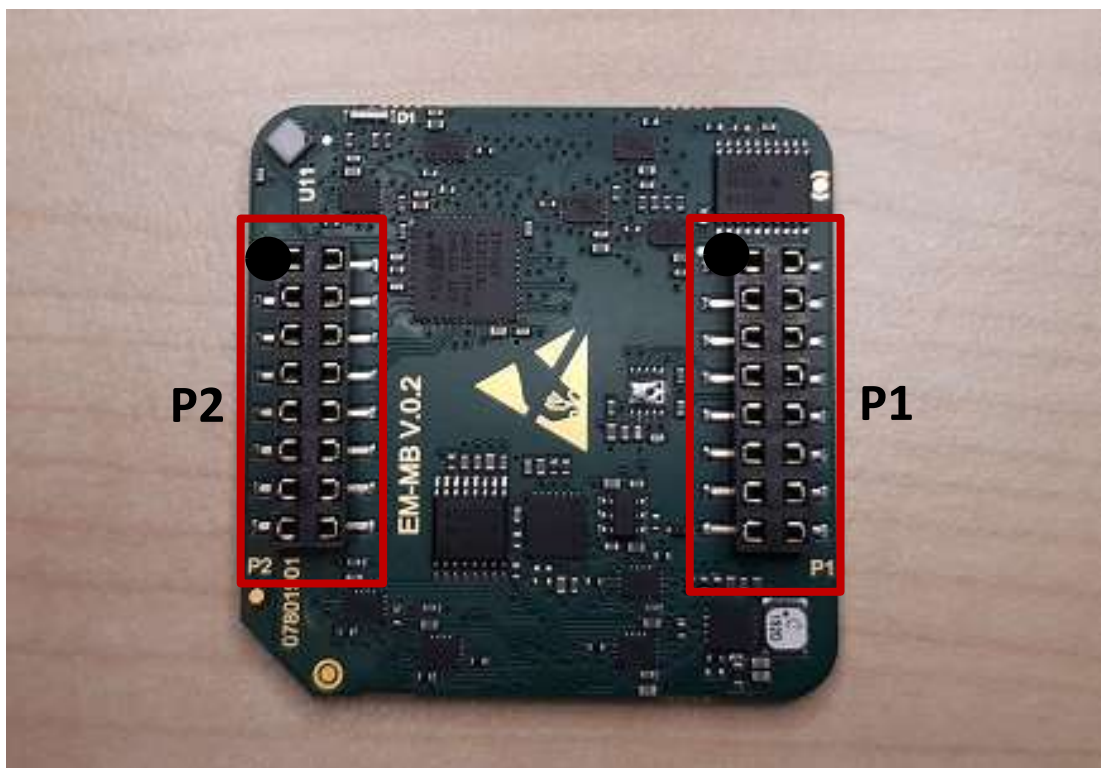
P2

I2C SCL	1	2	UART RX
I2C SDA	3	4	UART TX
SPI CS	5	6	SPI SCK
SWLCK	7	8	SPI MISO
GND	9	10	SPI MOSI
GND	11	12	GND
BOOT0	13	14	SWDIO
NRST	15	16	PMIC_EN

P1

NC	1	2	GND
NC	3	4	GND
NC	5	6	GND
NC	7	8	GND
3V3	9	10	GND
3V3	11	12	GND
VIN	13	14	GND
VIN	15	16	GND

2.4.1. Recommended operating conditions

- VIN: 2.3 V to 5.5 V
- MCU supply voltage: 3.3 V
- Logic input level, low: GND to 1 V
- Logic input level, high: 2.3 V to 3.3 V
- Max. Power Consumption 30 mA @ 5 V
- Max. supply current to external devices 500 mA at 3V3

2.5. Communication

2.5.1. UART
UART is the standard communication channel for the data output. The output format can be configured via this port, see 2.5.4 Data output.

- Baudrate: 115200
- Data bits: 8
- Stop bit: 1
- Parity: None

2.5.2. I2C
The MCU is configured as master. The internal communication takes place via this bus. In future, additional devices can be connected and/or the ML-model output can be provided via this port.

- Clockspeed: 100 kHz

2.5.3. SPI
ML-model output (data format 4 and 5). In future, additional devices can be connected.

- Smell Board SPI-Mode: Master
- Baudrate: 3,125 Mbits/s
- Frame Format: Motorola
- Data size: 8 bit
- First Bit: MSB
- Clock polarity (CPOL): Low
- Clock Phase (CPHA):   1 Edge

2.5.4. Data output
Default format is Data format 1. If a different format is selected, it will be saved and again executed after restart. By default, the ML-model output will not be communicated with LEDs.

Data format	Command	Output	Description
	G	V1.0.0;MB:00:a1:34:25:48\n	Firmware version; serial number
Data format 1 (default)	D1	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n	Raw-data output via UART
Data format 2	D2	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n start;class\n	Raw data with detected class output via UART
Data format 3	D3	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n start;Model output\n	Raw data with ML-Model as number via UART
Data format 4	D4	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n SPI:	Raw-data output via UART, detected class output via SPI

		start;class\n	
Data format 5	D5	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n SPI: start;Model output\n	Raw-data output via UART, ML-Model as number via SPI
Data format 6	D6	UART: start;CH1;CH2;…;CH64;Temperature;Humidity\n SPI: start;CH1;CH2;…;CH64;Temperature;Humidity\n	Raw data with detected class output via SPI
(default)	L0	As configured with D1, D2, D3, D4, D5 or D6	LED off
	L1	As configured with D1, D2, D3, D4, D5 or D6	LED on, only three classes can be displayed with the LED class 1 – green class 2 – red class 3 – yellow

Example output for data format 2:
start;271.0;271.1;270.8;270.8;2666.1;2666.8;2666.4;2666.6;26827.3;26831.1;26830.3;26831.8;268778.0;268746.3;268858.8;269068.2;270.7;270.7;270.6;270.7;2665.1;2666.7;2666.5;2667.2;26825.2;26832.6;26831.3;26831.9;269912.8;269058.1;269164.2;269354.8;270.0;270.0;269.0;270.0;2689.0;2700.0;2692.0;2708.0;26993.3;26984.1;26843.5;26830.0;269177.8;269049.0;269295.5;269169.8;271.5;271.6;271.4;271.5;2666.4;2666.8;2667.6;2668.2;26829.5;26842.5;26832.5;26829.3;268695.9;268975.2;269641.0;268687.0;26.809999;46.180000\n
start;Air\n

2.5.5. Error messages

Error message	Description
start;Bad connection to functionalization 1 (P1) 2 (P1) 5 (P2) 6 (P2)	Resistance values of functionalization 1 and 2 from detector 1 in socket P1 and functionalization 5 and 6 of detector 2 in socket P2 got to high resistance values. Repositioning of the detector may help.
start;Sensor Board not inserted\n	All resistance values at the sensor board got to help values. Please check connection between sensor board and main board.
start;Error init LMP\n	LMP91000 (AFE) is not replying. Hardware error.
start;Error init ADC\n	ADC is not replying. Hardware error.
start;Error init SHT\n	Temperature- and humidity-sensor (SHT) is not replying. Hardware error.
start;Error calibration\n	Calibration of AFE and ADC failed.

2.5.6. Configure the Smell Board

To activate the detection output via the LED it is necessary to send the command "L1" to the device. To do this, please follow the following steps.

Connect the Smell Board to your PC. The first step is to determine the COM port with which the device is connected to the PC. To do this, please right-click on the Windows button at the bottom left of your screen (see the following figure) and then on the "Device Manager" field. Alternatively, the device manager can also be found via the Windows search.
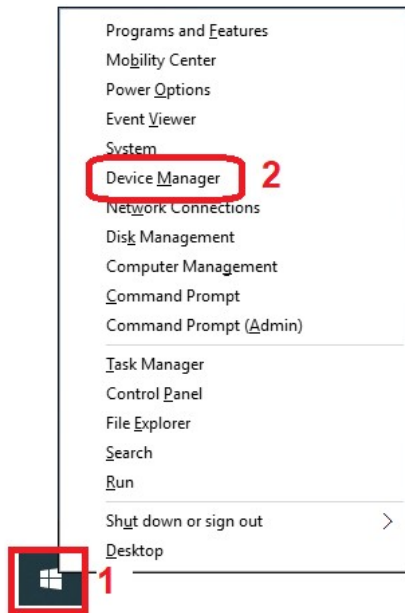
The following window appears. If you are logged in as a standard user. Confirm with OK. If you are logged in as an administrator, the window does not appear, and you are immediately taken to the device manager.
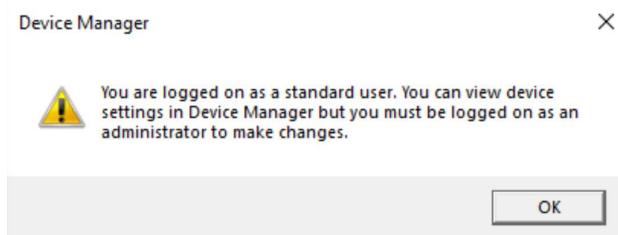
The device manager opens. Now expand the "Ports (COM & LPT)" field. If the Smell Board is connected to the PC, you should also see the red underlined line, probably with a different COM port. In the figure it is COM18.
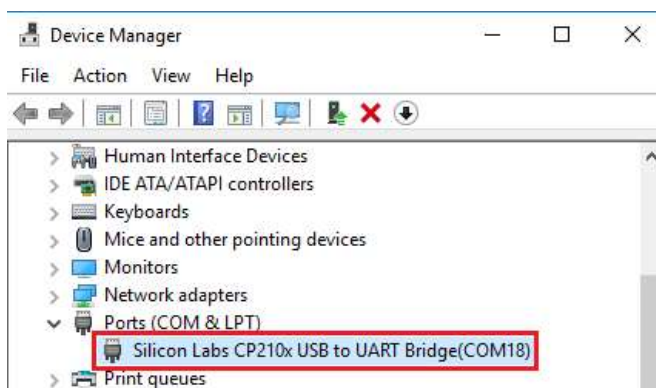
If you got the COM-Port insert it to the following Python script. This Script will give you the data output from the Smell Board. With usage send_command-function it's possible to configure the Smell Board.

```python
import serial.tools.list_ports

SERIAL_PORT = 'COM18'
SERIAL_BAUD = 112500
```

```python
def send_command(s, command):
    # Send EOL-terminated command
    s.write(('%s\n' % command).encode())
    # Ignore command echo
    line = s.readline().decode()
    print(line.rstrip())

def read_response(s):
    # Wait for command response. Strip EOL
    return s.readline().decode().rstrip()
try:
    s = serial.Serial(SERIAL_PORT, baudrate=SERIAL_BAUD)
    sensors = []
    count = 0
    number_ports = 0
    comports = []
    ports = serial.tools.list_ports.comports()
    # The command 'G' will give you the firmware version and SNR of the Smell
Board
    send_command(s, 'G' )
    while(1):
        if(s.inWaiting()):
            read_res = read_response(s)
            sensors.append(read_res)
            print("%s" % (sensors[-1]))
            sensors = []

except serial.serialutil.SerialException as e:
    print('ERROR: %s' % e)
```

2.5.7. Recognition of H_2S and NH_3

The Smell Board has a pre-installed ML model with a limited functionality of recognition of H_2S and NH_3 gases (low concentrations in air). To test its performance, we recommend to prepare two samples of a water solution containing these gases, about 100 ml each, following a short description below.

- Preparation of H_2S solution from the solid Na_2Sx3H_2O

Take one small crumb (size < 1mm) of Na_2Sx3H_2O, determine its weight X in milligrams at the analytical balance, it should be 1<X<3 mg. Prepare the stock solution using this small crumb of Na_2Sx3H_2O and DI water with volume of water in milliliter calculated as V (ml)=X*100/1.32. Solve this crumb of Na_2Sx3H_2O, mix well the solution $\Rightarrow$ stock solution. Take 90 ml DI water and 10 ml stock solution, mix them well $\Rightarrow$ ready. Keep the bottle with the prepared solution permanently tightly closed. The amount of H_2S generated by the prepared solution is enough for 4-5 exposures ca. 3 min each.

- Preparation of NH_3 solution from the 25% NH_3 solution

Take 100 ml DI water and add to it 0.1 ml 25% NH_3 solution $\Rightarrow$ ready. The amount of NH_3 generated by the prepared solution is enough for 10 exposures ca. 3 min each.

Each prepared water solutions have to be put in a flask with an opening of ca. 80mm in diameter. For exposing Smell Board to H_2S and NH_3 gases it can be placed onto the opening of each flask with detectors pointing down. Please notice that these water solutions should be used for such tests only and must be disposed after this use.

To see how to take the measurements for a good recognition have a look at this Video:

https://www.youtube.com/watch?v=v1LgW0KVOQc

This is a smell recognition demo with the Smell Board.
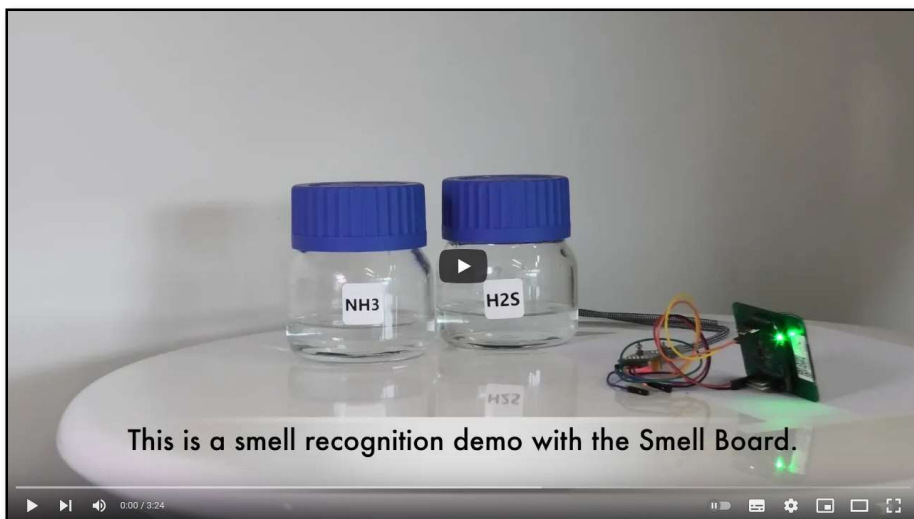
3.   Smell Annotator

The Smell Annotator app is a part of the electronic nose developer kit Smell Board. The Smell Annotator gives you a direct access to the data from the temperature, humidity, and smell sensors of your Smell Board device.

The Smell Annotator is an application to view, annotate, and store measurements from the Smell Board. Software is supported in Desktop (Windows) devices.

To download the Smell Annotator software please visit, http://smart-nanotubes.com/downloads/.

Scan Me

Figure 1. Smell Annotator download QR Code

3.1.   System Requirement

- For Desktop
  Please Make sure that your computer meets or exceeds the following system requirements before installing the Smell Annotator application.

From the desktop app version >= 1.1.1, no need to perform driver installation manually.

| Processer	Intel Core / AMD CPU
RAM	2 GB
Available Disk Space	300 MB
OS	Windows 10 and 11 supported

For the

desktop app version < 1.1.1.
Before you start the program, First, install the sensor drivers.

Download the appropriate version from the [Download driver](#).
(1) Go to the Downloads tab and download the Windows version of the driver (**CP210x Windows Drivers**).
(2) Unpack the zip file where you want to use the program.
(3) Install the VC redistributable package by running "CP210xVCPInstaller_x64.exe" in the extracted directory.
(4) Finally, double-click "Smell Annotator.exe" in the directory to run the program.
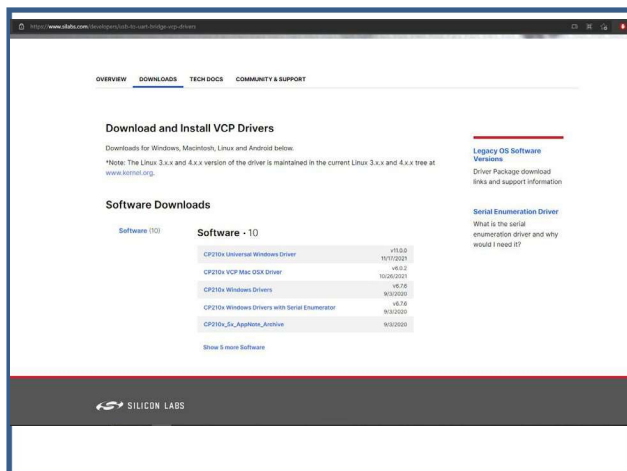
3.2.   How to take your smell measurement?

For smell recognition measurements using ML models provided in Smell Annotator app please refer to Chapter 3.4 of the Technical Manual for Smell Inspector (can be found in the Download web page mentioned above). For performing new smell measurements, the Smell Board can be used together with the Smell Annotator. To do so, the Smell Board device must be connected to the Smell Annotator application. The device can be connected to Smell Annotator desktop application (Windows) via USB connection.

The sequence of initial steps is provided below.

3.3.   Steps to follow

Step 1 – Signup and set up an account for Smell Annotator. Next, Sign In to Smell Annotator.
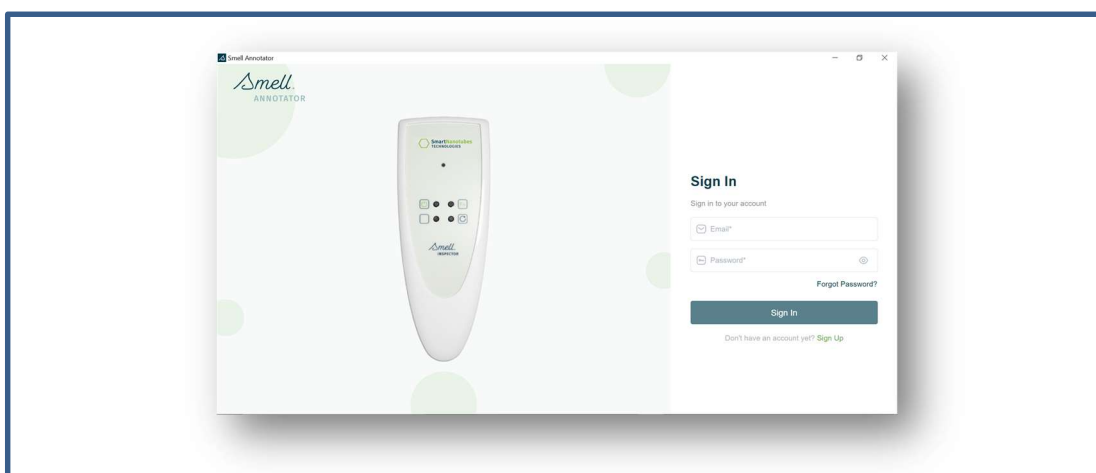
Figure 2. Signup and setup an account for Smell Annotator

Step 2 – Connect the Smell Board via **USB-UART-Converter and USB-C-Cable to the app**.
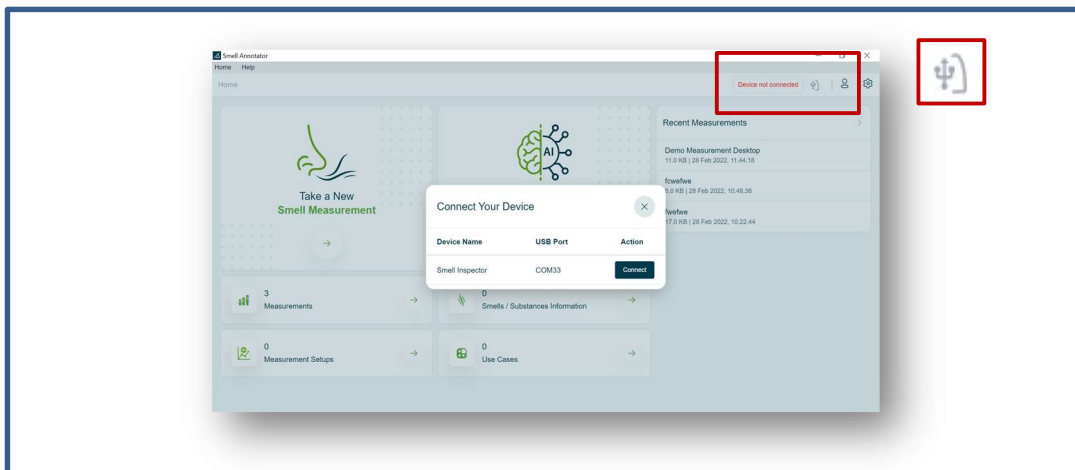
Figure 3. Connect the Smell Board

Step 3 – Once the Smell Board is connected, the connection status is shown in the toolbar and notification will pop up. The device is ready for taking measurement; however, it is strongly recommended to wait about 20 min for the detector stabilization in a new environment and the air flow.
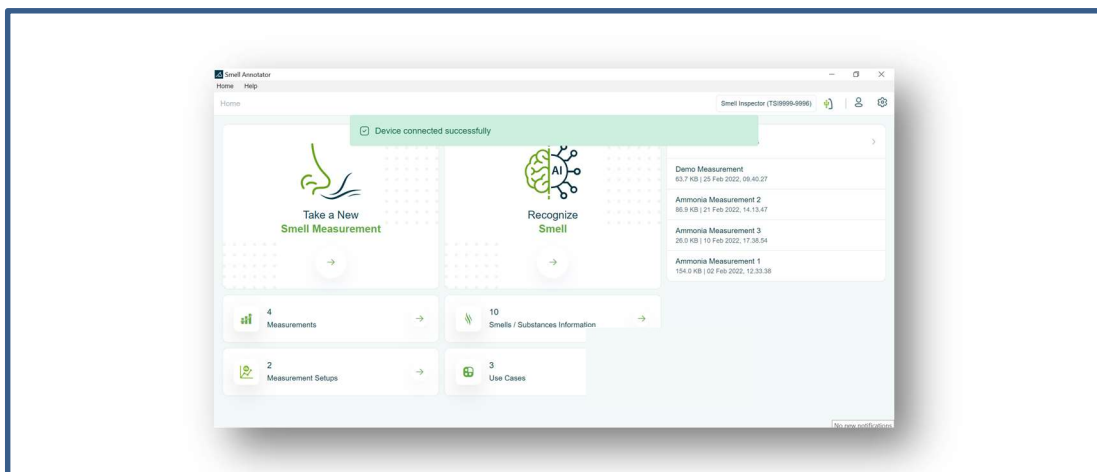
Figure 4. Smell Board connected

Step 4 – Proceed by clicking "Take a New Smell Measurement"
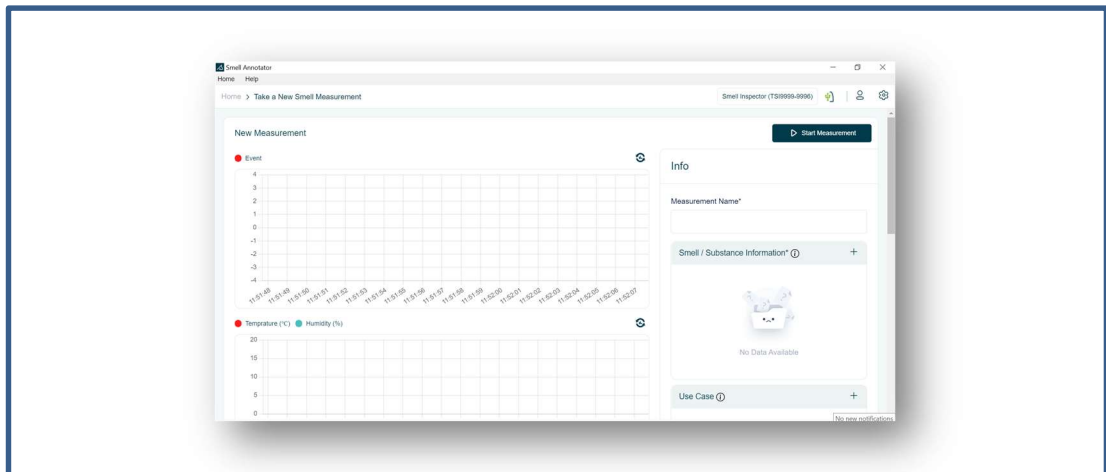
Figure 5. Click "Take a New Smell Measurement"

Step 5 – Initialization process (takes few seconds)
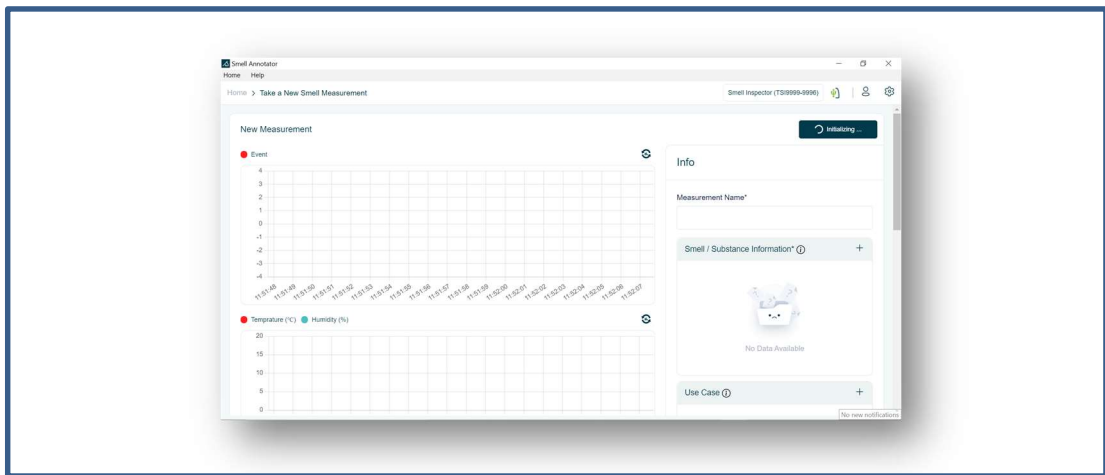
Figure 6. Initialization of a new measurement

Step 6 – Measurement started: the software shows the averaged real-time smell sensor response in the upper plot and temperature and humidity values (in °C and %) in the lower plot.
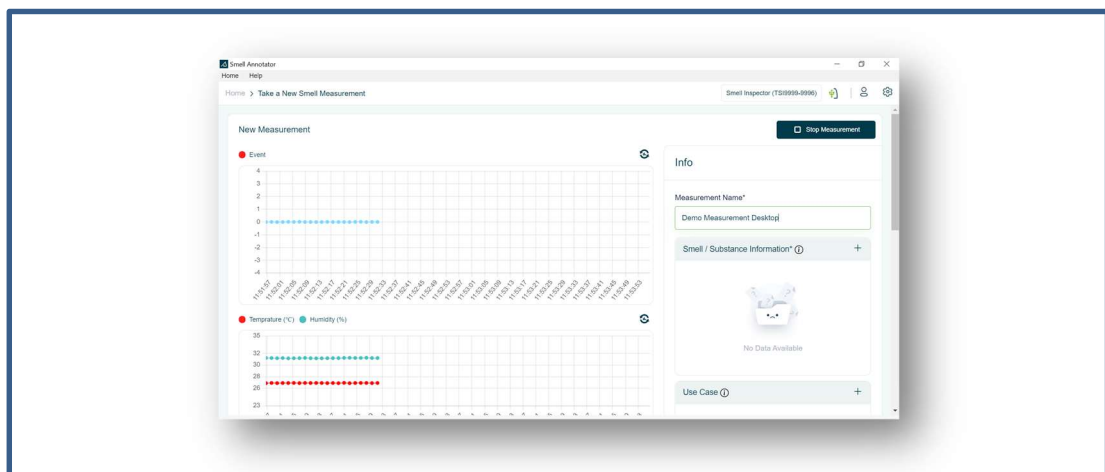
Figure 7. Real time visualization of the measurement

Step 7 – Add Information: **Name**, **Smell/Substance information** (compulsory) and Use Case, Measurement Setup (optional).
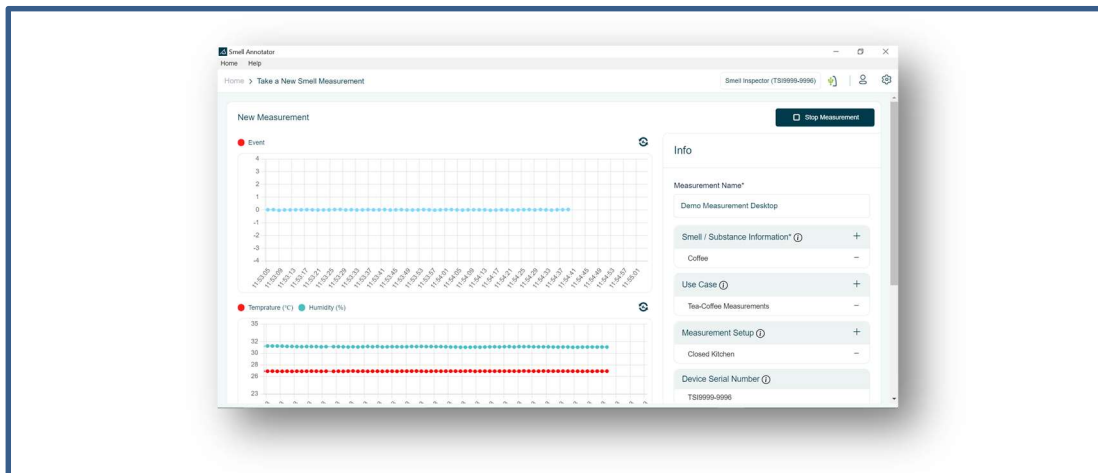
Figure 8. Add Information

Step 8 – Stop and Save Measurement
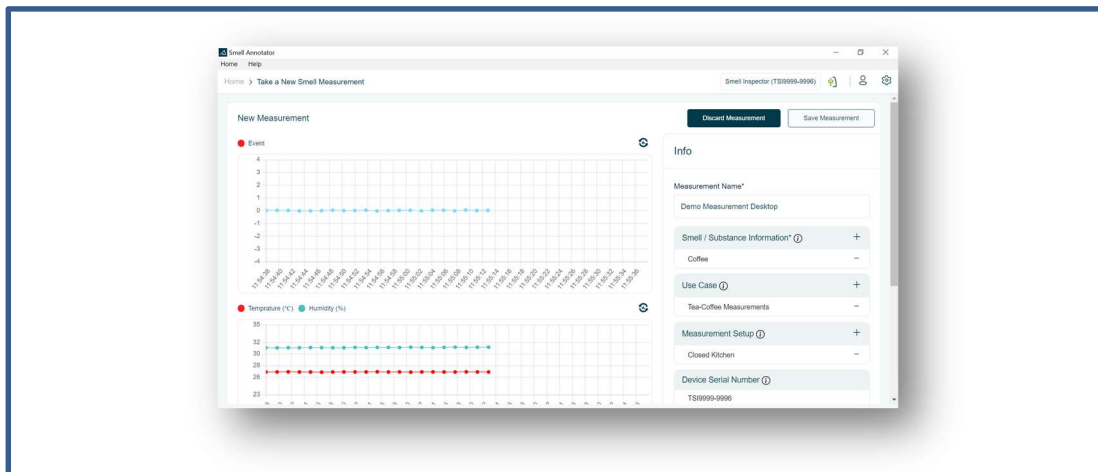
Figure 9. Stop and Save Measurement

Step 9 – View saved measurement in the Measurement list.
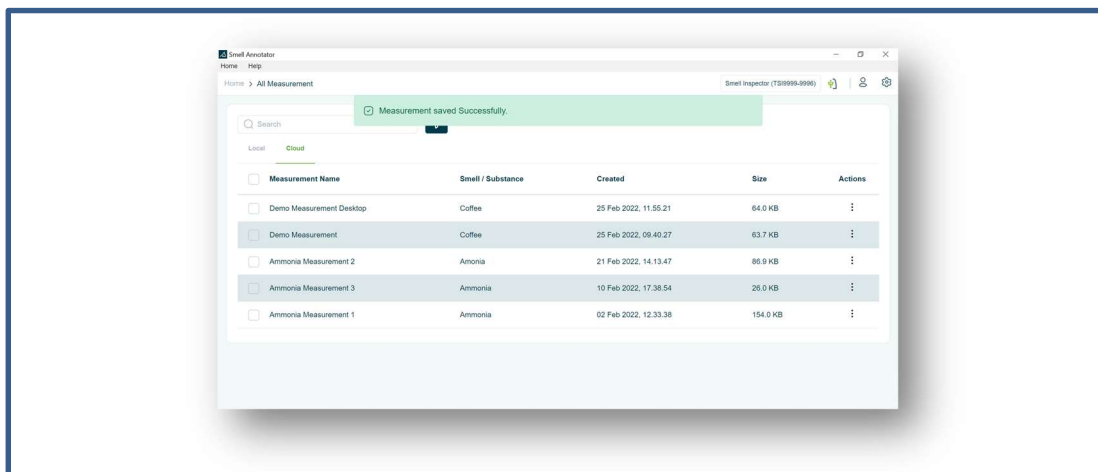
Figure 10. View in the Measurement list
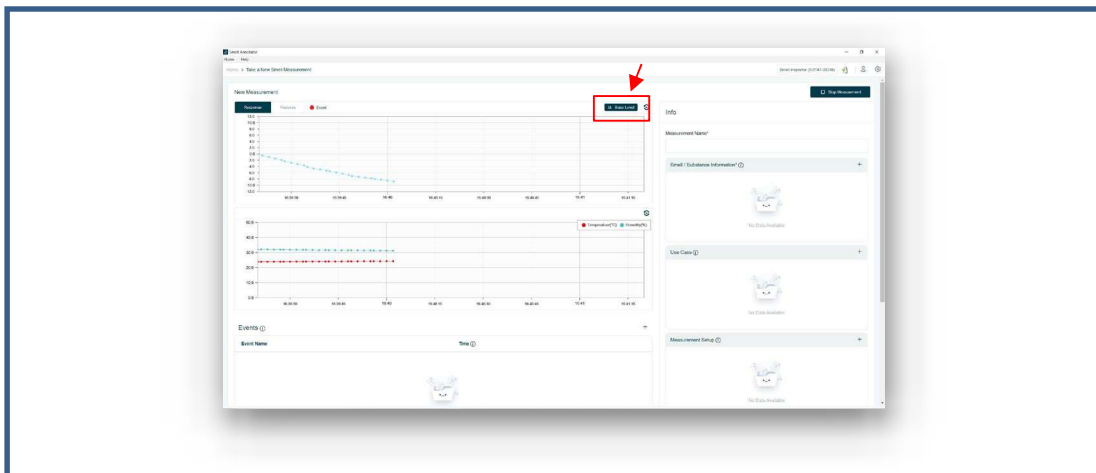
Figure 14. Reset Base Level in the ongoing measurement

3.4.   How to add Base level?

Reset Base Level:

The reset base level will set a new baseline for the ongoing measurement. A baseline is a fixed point of reference that is used for comparison.

It serves as a reference point for all subsequent points in the measurement.

The Base Level can be set to the time when you expect to see a change in measurement values (in the graph) or want to see a change in measurement response in the graph at that time. When the Base level is added to ongoing measurement, all future measurement points are shown in the graph as changes to the base level point.

3.5.   How to export the measurement?

To be able to export the saved measurement, go to 'measurement list' > Click 'detail icon' () > Click 'Export'. Selected measurements will be exported as a CSV (comma-separated values) file. In the desktop app, the measurement will be saved in the download folder.
In the mobile app, the measurement will be exported to the selected folder.
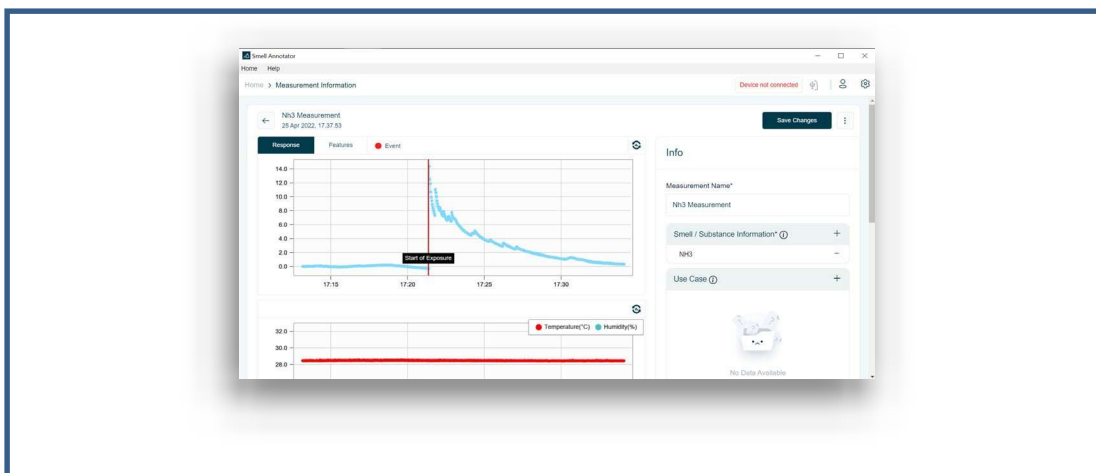
Figure 15. Export a Measurement as CSV file

3.6. How to view the Feature graph?

The featured graph represents the feature values of the Smell measurement. It gives the inside of the measurement.
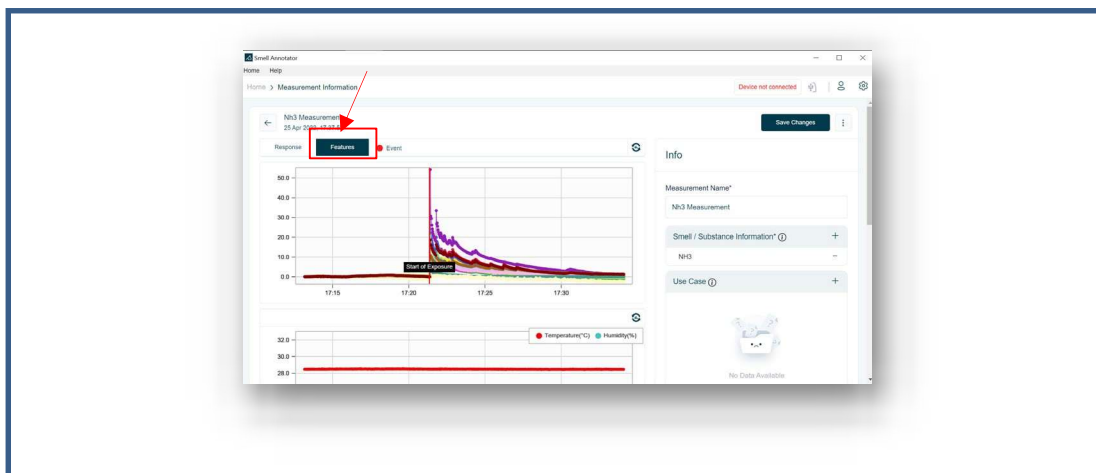
Figure 16. Feature Graph

3.7. Measurement Analysis

Measurement Analysis provides you with an information about smell measurements. There are four types of analyses available. 'PCA,' 'LDA,' 'Radar Plot of Each Substance,' and 'Radar Plot of Each Measurement.' This information can be used to evaluate whether the collected measurements can be used to discriminate between two or more smells based on pattern recognition.

Please follow the steps below to perform a measurement analysis.

Step 1   Navigate to the 'Home' screen. Select 'Analysis.' The measurement listing screen will be opened.
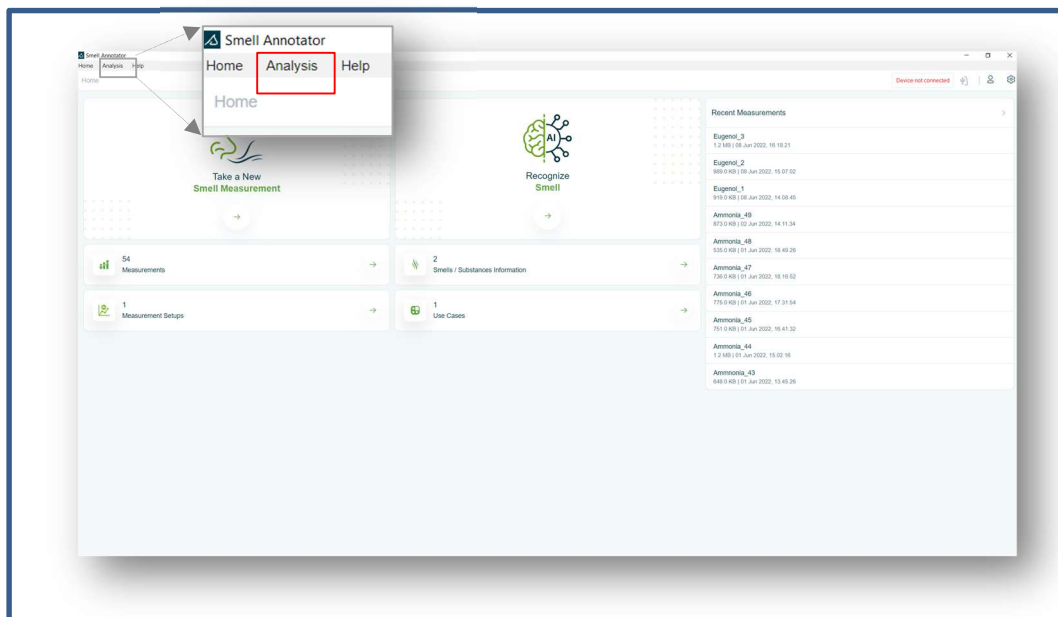
Figure 17. Navigation to Analysis

Step 2   There are two panels on the current screen. On the left panel, there is a measurement listing

view where you can select the measurements for which you want to perform the analysis. Analysis graphs will be visible on the right panel. Each measurement used for Analysis should last performed following the protocol described in FAQs "1. How to take measurements", see page 20. You will only be able to select the measurements that fulfil the mentioned requirement.
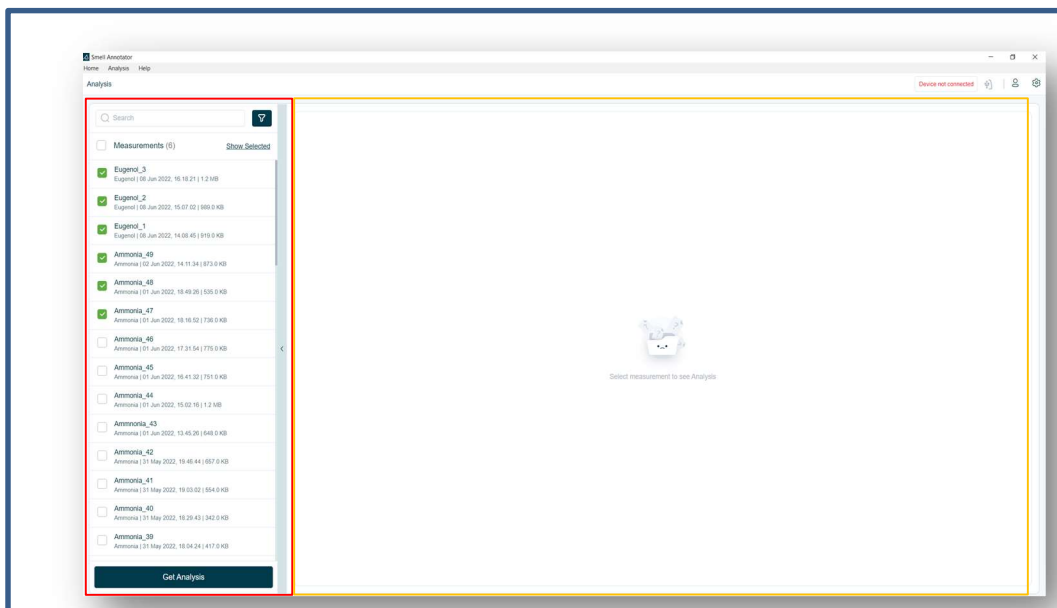
Figure 18. Analysis Screen – Measurement selection

Step 3   Once you have chosen the measurements from the list, you may click the 'Show All' or 'Show Selected' button to see only the chosen measurements or all the measurements in the list, correspondently. Now, click the 'Get Analysis' button to get the Analysis of the selected measurements.
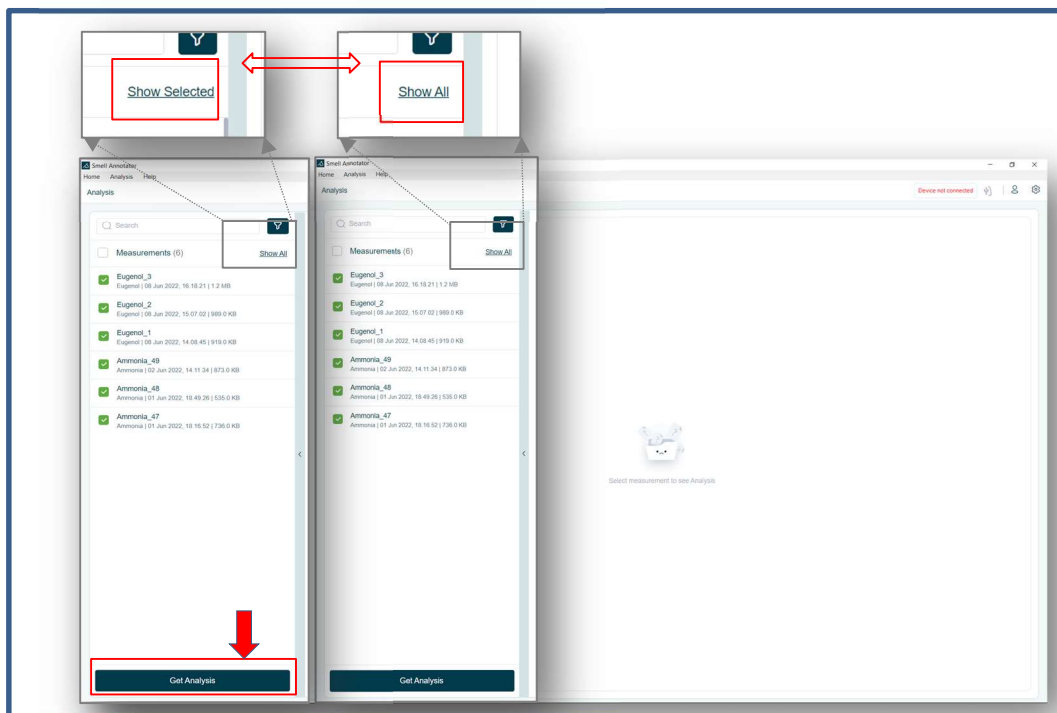
Figure 19. Analysis Screen –Get Analysis

Step 4   Now you should be able to see the screen below. Only in case at least two measurements with the same smell information are selected an LDA graph will be generated. Otherwise, the LDA graph

cannot be provided.
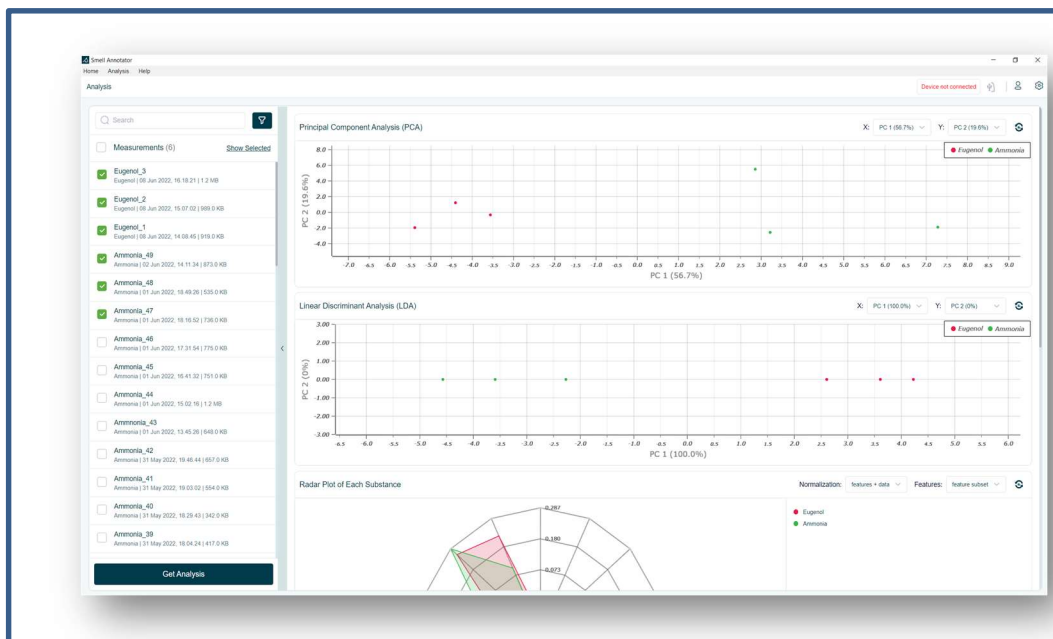
Figure 20. Analysis Screen – Analysis Graphs

PCA Analysis:

Principal Component Analysis (PCA) reduces the complexity of high-dimensional data while preserving patterns and trends. It is done by condensing the data into fewer dimensions that serve as feature summaries. PCA aids in comprehending the similarities between features.

For more information, visit (https://en.wikipedia.org/wiki/Principal_component_analysis)

We can deduce the following information from the PCA analysis:
(1) whether multiple measurements from the same smell can be combined in a group.
(2) whether two different smells can be presented as two separated groups.
(3) how large is variance of the same smell measurements within its smell group.
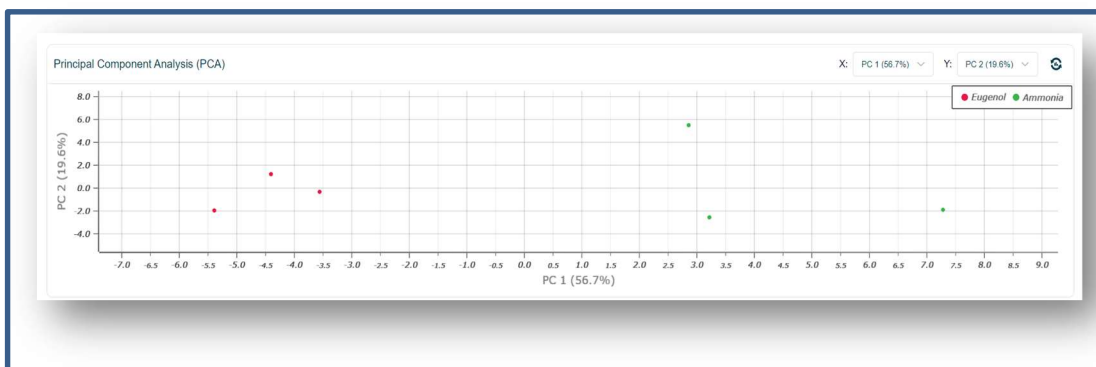
Figure 21. Analysis Screen – PCA

Here Option X and Y is to select the Principal Component (PC) for the PCA analysis. Here the PCx (x%) is the explained variance ratio in the percentage [%]. The explained variance ratio is the percentage of variance that is attributed by each of the selected components. The range can be in between [0-100%].

LDA Analysis:

Linear Discriminant Analysis (LDA), also known as normal discriminant analysis or discriminant function analysis, is a generalization of Fisher's linear discriminant, a method used in statistics and other fields to identify a linear combination of features that characterizes or distinguishes two or more classes of objects or events.
For more information, visit (https://en.wikipedia.org/wiki/Linear_discriminant_analysis)

We can deduce from the LDA analysis whether two different smell measurements can be separated.

Option X and Y are used to choose the Principal Component (PC) for the LDA analysis. The PCx (x percent) represents the explained variance ratio in percentage [percent]. The explained variance ratio is the percentage of variance attributed to each of the chosen components. The range can be between [0% and 100%].
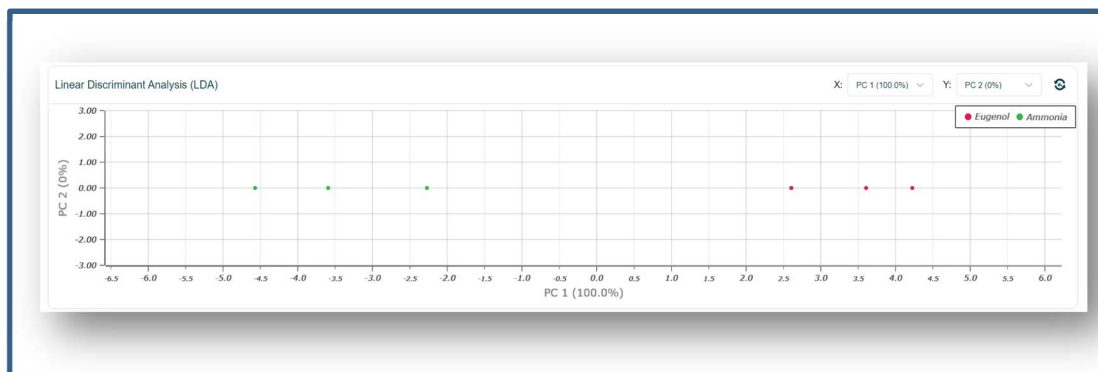
Figure 22. Analysis Screen – LDA

Radar Plot of Each Substance Analysis:

This graph displays the **average** patterns of each Smell/Substance, providing you with a substance-specific feature pattern. Feature subset and all Feature are the two types of feature selection.

We can deduce the following information from the 'Radar plot of Each Substance' analysis:
(1) Comparison of averaged Smell/Substance patterns from all selected measurements.
(2) Whether the averaged Smell/Substance patterns for different Smells/Substances are similar or distinct.
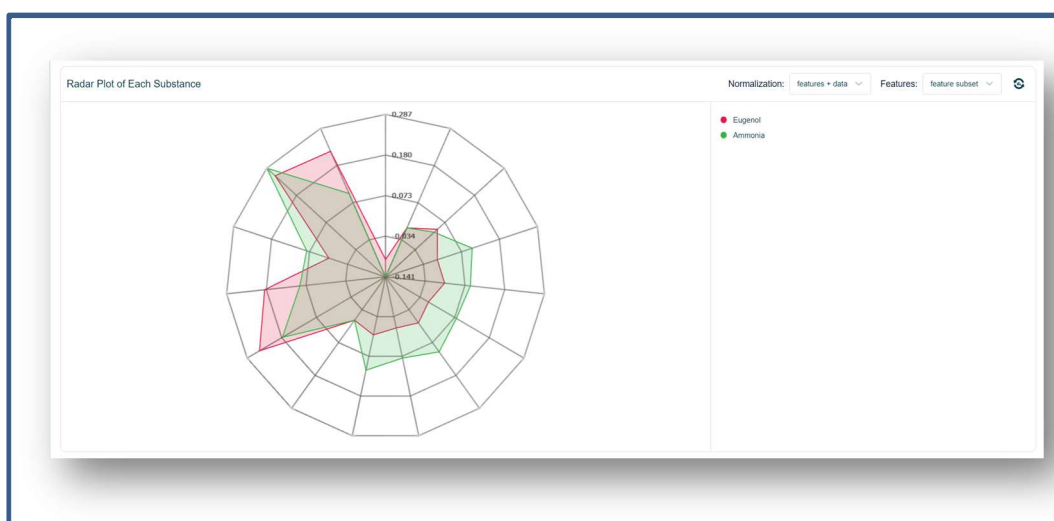
Figure 23. Analysis Screen – Radar Plot of Each Substance

Option Normalization: [Features + data]
1. Features + data: Normalization is performed on both the features and the

individual measurements.

Option Features: [Feature subset, All features]
1. Feature subset: Feature subset is the 15 features from the measurements.
2. All features: All features provide two additional parameters for every individual feature. There are 45 feature parameters in total.

Radar Plot of Each Measurement:

This graph will display the patterns of each measurement, providing you with a measurement-specific feature pattern.

We can deduce the following information from the 'Radar Plot of Each Measurement' analysis.
(1) Comparison of individual measurements patterns.
(2) Whether individual smell measurement patterns are similar or distinct.
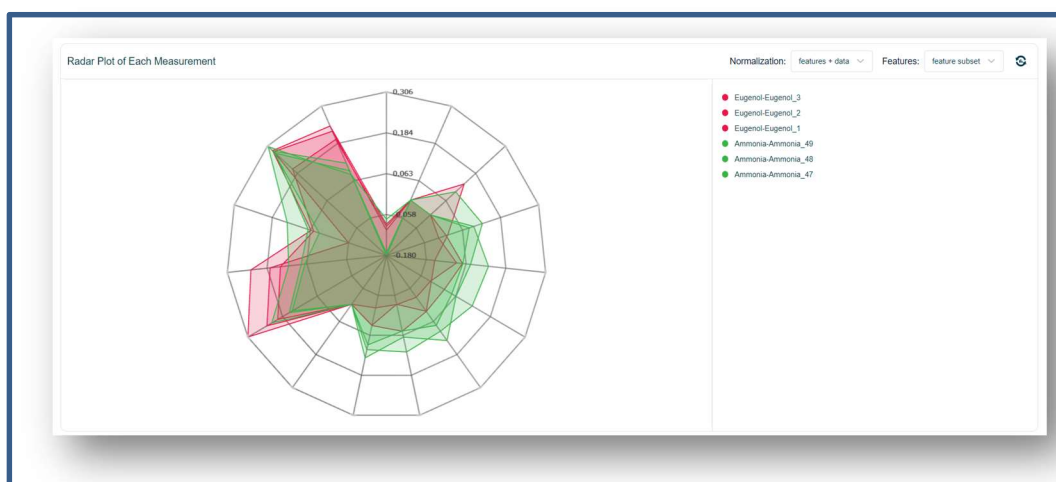
Figure 24. Analysis Screen – Radar Plot of Each Measurement

Option Normalization: [None, Features, Features + data]
1. None: When none is selected for normalization, the data is not normalized. The relative response $\Delta R/R_0$ [%] for every individual feature is directly used to create the pattern.
2. Features: The values of features are normalized.
3. Features + data: Normalization is performed on both the features and the individual measurements.

Option Features: [Feature subset, All features]
1. Feature subset: The 15 features from the measurements are included in the feature subset.
2. All features: All features provide two additional parameters for every individual feature. There are 45 feature parameters in total.

4.   FAQs

4.1.   Account

4.1.1.   I lost my password. Need help resetting it.
Choose "Forgot your password?" or "Forgot Password?" when signing in and enter your email address or phone number. We'll send you a link to reset your password.

4.2.   Smell Annotator

4.2.1.   Can I Use Smell Annotator without SignIn?
No, you cannot use Smell Annotator unless you sign in.

4.2.2.   Is the Smell Annotator software compatible with all platforms?
The Smell Annotator app is currently available for Android and iOS devices, as well as Windows laptops and desktop computers.

4.3.   Smell Board

4.3.1.   Why is the USB connection not working?
It is possible that the correct USB driver is missing from your system. It is necessary that you download and install it from https://www.silabs.com/developers/usb-to-uart-bridge-vcp-drivers.

4.3.2.   How do I connect the Smell Board to the Smell Annotator?
The Smell Board device can be connected via the included USB-UART-Converter to a Windows PC or laptop.

4.3.3.   Where can I update the Smell Board firmware?
Desktop version of the Smell Annotator app supports firmware update. Disconnect the Smell Board from the Smell Annotator. Click on Settings ⚙ in the top right corner, there you can find the menu tab Flash firmware. Select the COM-Port of your PC connected to the Smell Board and the device type. Choose the desired firmware and click Flash. It will take some minutes until the firmware is updated. In the end you will see this window and the message "OK finally".
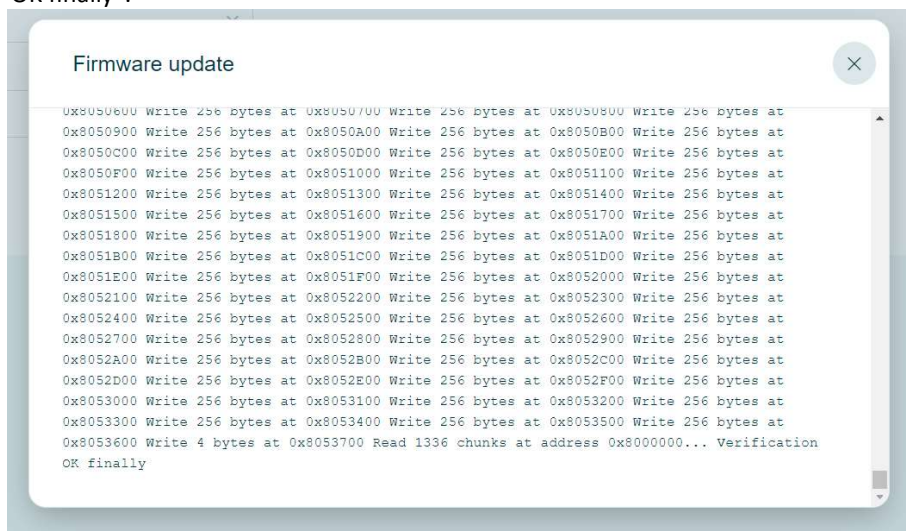
4.3.4.   Do different devices react to the smell in the same way?
Yes, given the same measurement environment, different devices respond similarly to the same smell. It's important to understand that as sensors are highly sensitive when you change the measuring environment, the reaction can vary noticeably.

4.3.5.   How should the Smell Board device be handled during the measurement?
Please exercise caution when taking measurements with the device in your hand. When performing the

measurement, try to keep the device in a more stable position. During the exposure, the device should not move. Variations in airflow can lead to inaccurate measurements if precautions are not taken.

4.3.6.   I have some sensors that always return <300, are they broken or is the gas not present?
This range may be returned by the sensor's first and last two channels. These are reference channels. This is completely normal behavior.

4.4.   Measurement

4.4.1.   How to take the new smell measurement?
To be able to annotate the Smell Measurement, it should be taken with the standard steps. Measurement is divided into 3 states,
Initial, Exposed and Recovering Initial – 10 minutes Exposed – 5 minutes
Recovering - Wait for the response/graph to return to its original state

       Step 1   Connect the Smell Board device to the Smell Annotator.
       Step 2   Start the measurement.
       Step 3   Initial State of measurement for 10 minutes.
Put the device in the smell neutral environment for about 10 minutes where there is no influence of the measuring smell in the measurement.
(After 10 minutes of the start of the measurement)
       Step 4   Now as you want to measure the smell, please put the Smell Board near the smell substance.
Add the event as changing the measurement state. Exposed state of the measurement for 5 minutes.
(After 5 minutes of smell exposure)
       Step 5   Now take away the smell substance or take the device away from the smell substance.
To be able to measure the smell substance correctly, one needs to measure normal air (neutral smell environment) for about 10 minutes.

It is not advisable to breath directly into the smell/substance sample during exposure.

4.4.2.   Why are some resistance values very high?
The channels with the feature 999 (see 6 Insights of the Measurement) are not relevant for the Smell Board and can be ignored.
The conductance between the nanotubes and the connector and the PCB is realized with a very thin gold layer. That's why it is very important to handle the carefully and do not touch the sensors. It seems to be that the gold layer is scratched at the contact pins. To solve this issue, it's necessary to reposition the Detector by opening the connector with the black handle and move the Detector slightly with a tweezer e. g. 1 mm to another contacting position. Close the connector and check if the error is gone.
If the error appears the Smell Board should print an error message via UART and the LED should blink twice red and once green. If you connect it with the UART-USB-Converter to your PC you should see a similar message like the following one:

start;Bad connection to functionalization 9 (P2) 6 (P2) 5 (P2) 15 (P4) 13 (P4) 12 (P4) 8 (P4)

In the brackets is written which connector you have to reposition. In this example it is P2 and P4. The designators are written on the sensor board. Please have look at the following picture.
If the conductance between the sensor and the connector is established again the error message should go away.
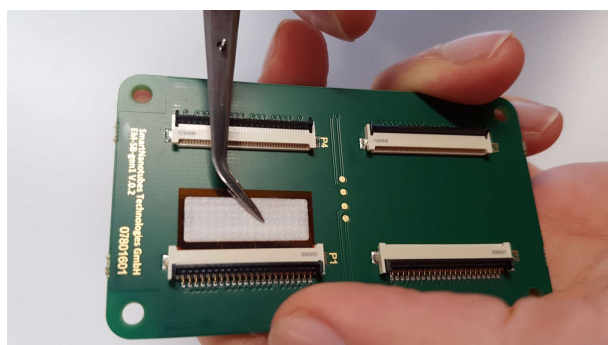
4.4.3. What are the temperature and humidity values in the graph?
The temperature and humidity values in the measurement correspond to the temperature and humidity (air flow) inside the device. These values should not be interpreted as the temperature and humidity of the normal environment outside of the device. However, the external environment may have an impact on the device's internal environment.

4.4.4. Is it possible to see all the channels in visualization?
Yes. You can view 15 feature channels in saved measurements using feature graph.

4.4.5. What are the three states of the measurement?
The measurement of smell is divided into three stages.
First, there is an "*initial state*" in which the device is exposed to a neutral environment, isolated from any smell that might change the measurement environment.
Second, in the "*exposed state*" the device is exposed to the smell or substance, and the resulting reaction or response is measured and reflected in the graph.
Third, in the "*recovering state*" the device is separated from the smell or substance element and placed in a neutral or normal environment. Because the exposed smell or substance has impacted the sensors, it may take a few minutes to restore them to their normal state.

4.4.6. What is the event in the measurement?
Measurement can be divided into three stages. An "event" is used to keep track of changes in the measurement stage while measuring. A machine learning model will be trained to recognize smells based on the events recorded during the measurements.

4.4.1. Can multiple smell measurements one by one without having a delay?
It is best practice to avoid measuring different smells one after the other. A single smell should be measured in a single measurement in a normal use case. When measuring multiple smells in a single measurement, the sensors may not fully recover from the previous smell and measuring a new smell before the sensors have reached a stable state may result in a mixed response in the measurement, making it not the correct measurement for the smell.

4.4.2. Is there any best practice to do the measurement?
Switch on the device for at least 30 minutes before measuring the actual smell for the best stabilization.

4.4.3. About measurement drifts in the measurement, Is it normal?
➢ Only drift as a response. This is possible due to a shorter distance of the smell board device to the substance or smell. Place the smell board device as close to the smell substance as possible, but not directly on the substance (keep it at a safe distance).
➢ This is also possible due to shorter measurement durations, which occur when the device is not exposed to the smell substance for enough time to obtain an accurate response. It is advisable to expose the smell substance to the Smell Board for at least 5 minutes.

4.4.4. Are we able to access the raw measurements collected by other users or internal measurements from the SNT?
Unfortunately, we cannot share the other user or internal smell measurements.

4.4.5. What do I expect as a response in the measurement graph from the smell measurement?
Many factors influence measurement response, including the type of smell substance, measurement environment, and concentration of the smell substance. We observed a sensor response of (a negative response of -50 percent to a positive response of +11000 percent in the measure values when exposed to various smell substances under different conditions).

4.4.6. What if the measurement environment was changed during the measurement?
If you remove the device from a closed environment (take it out of the bag, close the car, move it from one room to another), you must allow at least 30 minutes for stabilization before proceeding with the actual measurement

or exposing it to the smell substance again.

4.4.7. Can other smells or changing smell environment affect the actual measurement?
In most cases, measurement should be done in a smell-free environment. A foreign smell in the measurement environment can have an impact on the sensor response. When measuring, it's important to take this into consideration. (E.g., measurements are taken when the perfume is applied to the body.)

4.4.8. Is it possible for two measurements of the same smell substance to have varied graph responses?
If you're taking many measures of the same smell, be sure they're all done in the same environment. Alternatively, due to the influence of the other environment, you can expect a different reaction in measurements with the same smell.

4.4.9. Is there a list of which sensors measure what, such as nitrogen dioxide?
All the sensors respond to gases. Each sensor responds differently to various gases.

4.5. Recognize Smell

4.5.1. The 'Recognize Smell Line' is appearing in the plot panel with a delay. What could be the reason?
One of the possible reasons could be a poor internet connection. For smell recognition, the raw measurement data are sent to our server, and the recognition information is sent back to your PC or mobile device.

4.5.2. Which smells can I recognize with Smell Board?
The Smell Board uses a specific ML model that can only recognize the smells listed in the model information. It's important to note that the model can only predict and identify smells it has been trained to recognize. To see a list of smells/substances that the model can correctly identify, refer to the 'Model Info' section.

4.6. Detectors

4.6.1. Is there a list of which sensors measure what, such as nitrogen dioxide?
All the sensors measure the gases. Each sensor responds differently to various gases.

4.6.2. Does the sensor return a default value if it doesn't measure anything?
Yes, it could be less than 300 Ohms.

4.7. Other

4.7.1. Where can I find the privacy policies and the terms of use?
You will find the data policy for our software on our official download page for the software.

Privacy Policy: https://smart-nanotubes.com/smellannotator/privacy-policy/

Terms of Service: https://smart-nanotubes.com/smellannotator/termsofservice/

4.7.2. How can I get in touch with IT-Support?
You can send the email to our IT support team.
email: it-support@smart-nanotubes.com

4.7.3. Can we access raw measurements collected by other users or internal SNT measurements?
Unfortunately, we are unable to share the other user's or internal smell measurements.

4.7.4. Can you tell me how you use AI and what approach you take, or is that a trade secret?
Our apologies, but we are unable to provide information about our technology, and we hope you can understand our position.

5. Operating the Smell Board without Smell Annotator

5.1.1. Please refer to chapter 2.5.5 Error messages

Error message	Description
start;Bad connection to functionalization 1 (P1) 2 (P1) 5 (P2) 6 (P2)	Resistance values of functionalization 1 and 2 from detector 1 in socket P1 and functionalization 5 and 6 of detector 2 in socket P2 got to high resistance values. Repositioning of the detector may help.
start;Sensor Board not inserted\n	All resistance values at the sensor board got to help values. Please check connection between sensor board and main board.
start;Error init LMP\n	LMP91000 (AFE) is not replying. Hardware error.
start;Error init ADC\n	ADC is not replying. Hardware error.
start;Error init SHT\n	Temperature- and humidity-sensor (SHT) is not replying. Hardware error.
start;Error calibration\n	Calibration of AFE and ADC failed.

Configure the Smell Board. It is described there how to connect the Smell Board to your PC.

6. Insights of the Measurement

The measurement consists of 64 channel resistance value cycles plus temperature and humidity values. The 64 channels are made up of various types of feature channels. Each feature channel has its own smell sensitivity characteristics.

There are 16 channels in each detector. Each channel represents a different set of characteristics. There are various types of feature sets in current detectors, such as Type 1, Type 2, Type 3, and Type 4.

Detector Type	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15	Ch16
Type1	999	999	11	11	11	3	3	3	2	2	2	1	1	1	999	999
Type2	999	999	999	999	999	9	9	9	6	6	6	5	5	5	999	999
Type3	999	999	14	14	14	10	10	10	7	7	7	4	4	4	999	999
Type4	999	999	15	15	15	13	13	13	12	12	12	8	8	8	999	999

#Note: Ignore channel value with 999 in the measurement.

Detector Type	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15	Ch16
Type1	999	999	f11	f11	f11	f3	f3	f3	f2	f2	f2	f1	f1	f1	999	999
Type2	999	999	999	999	999	f9	f9	f9	f6	f6	f6	f5	f5	f5	999	999
Type3	999	999	f14	f14	f14	f10	f10	f10	f7	f7	f7	f4	f4	f4	999	999
Type4	999	999	f15	f15	f15	f13	f13	f13	f12	f12	f12	f8	f8	f8	999	999

#Note: Ignore channel value with 999 in the measurement.

In the Smell Annotator app, in the feature graph, we took the mean average of individual channels with the same feature characteristics and displayed them.

For example, in the measurement graph for detector Type1, you will see [f11, f3, f2, f1]. The same is true for Types 2, 3, and 4.

All channels with feature 999 are Base channels which are found in detector channels 1, 2, 15, and 16. We normally do not include them in the graph because it only contains base resistance values.

In Type2 detector set, channel 3,4,5 (ch19, ch20, ch21) also make as base channel and we do not consider into actual measurement graph.

So, in a typical measurement with detector types 1, 2, 3, and 4, there will be a total of 15 feature channels. If you want to use Smell Board without the Smell Annotator app, you must consider these factors.