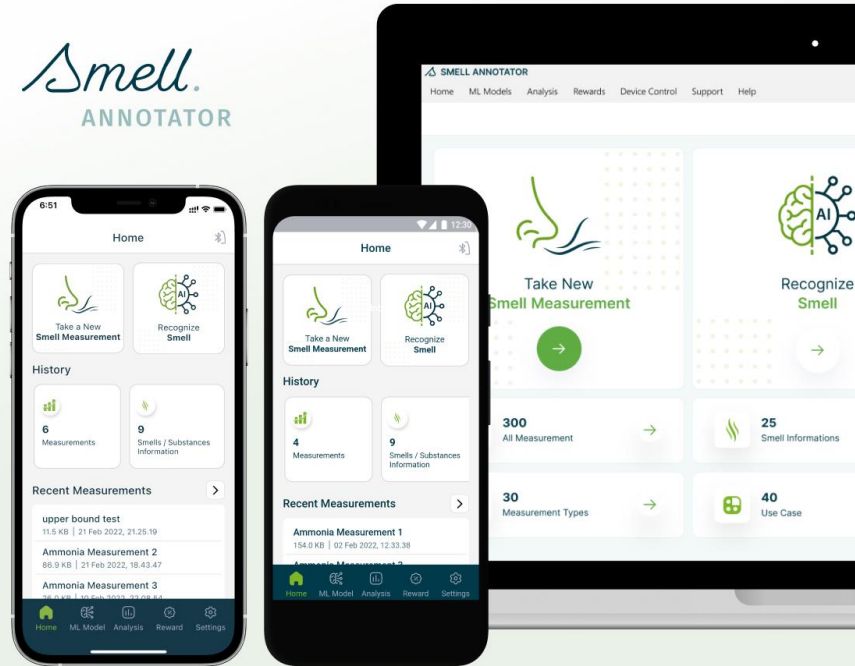


Smell.
INSPECTOR

Smell.
ANNOTATOR

Explore your own
smell-related applications!



Technical Manual

Smell Inspector

Table of Contents

1. Overview	5
1.1 Purpose of the Manual	5
1.2 Getting Started	5
1.2.1 Step 1: Unpacking Your Smell Inspector	5
1.1.2 Step 2: Installing the Smell Annotator	5
1.1.3 Step 3: Connecting the Smell Inspector	5
1.1.4 Step 4: Recording Smells	5
1.1.5 Step 5: Recognizing Smells	5
1.3 Product Overview	6
1.3.1 Smell Inspector	6
1.3.2 Smell Annotator	7
1.4 Device Control	9
1.4.1 Button Operation	9
1.4.2 LED Readings	9
1.5 Terminology and Meanings	10
1.5.1 Smell / Substance Information	10
1.5.2 Events	10
1.5.3 Local (Offline measurements)	11
1.5.4 Cloud (Online measurements)	11
2. Smell Inspector	12
2.1 Modes of Operation	12
2.1.1 USB Operating Mode	12
2.1.2 Bluetooth Operating Mode	12
2.1.3 Power Saving Mode	12
2.2 Things to Keep in Mind	12
2.2.1 Smell Inspector Overview	13
2.2.2 Smell Inspector Operation	13
2.2.3 Detectable Gases and Smells	13
2.2.4 Gas Detector Sensitivity	13
2.2.5 Detector Replacement	13
2.2.6 Detector Cleaning	13
2.2.7 Smell Inspector Training	13
3. Process Steps	14
3.1 Setup an Account	14
3.2 Connection to Smell Annotator App	14
3.3 Smell Measurement for Annotation	15
3.3.1 Step 1: Start New Smell Measurement	15
3.3.2 Step 2: Add Measurement Information	17
3.3.3 Step 3: Stop and Save Measurement	17
3.3.4 Step 4: View saved measurement in the Measurement List	18
3.4 Recognize Smell Measurement	19
3.4.1 Step1: Start Recognize Smell Measurement	21

Technical Manual

3.4.2 Step 2: Select ML Model	21
3.4.4 Step 4: Measurement Started – Initial Stabilization	23
3.4.5 Step 5: Expose Device to Smell/ Substance.....	23
3.4.6 Step 6: Expose Device to Smell/ Substance.....	24
3.4.7 Step 7: End Exposure.....	24
3.4.8 Step 8: Correct Event name for better reference	25
3.4.9 Step 9: Stop Measurement	26
3.4.10 Step 10: Save Measurement	26
3.4.11 Step 11: Measurement saved Successfully!	29
3.5 Reset Base Level.....	30
3.6 Export Measurement.....	31
3.7 View the Feature Graph.....	31
3.8 Measurement Analysis	32
3.8.1 Step 1: In Home Screen, Select “Analysis”	32
3.8.1 Step 1: Select Measurements to Analysis	32
3.8.3 Step 3: Click on ‘Get Analysis’	33
3.9 Fan Control.....	37
3.9.1 Step 1: Go to <i>Setting > Application > Fan Control</i>	37
3.9.2 Step 2: Turn On ‘Fan Control’	37
3.9.3 Step 3: Change the fan speed (i.e., Setting Fan Speed to 0)	38
4. FAQs	39
4.1 Account	39
4.1.1 How can I reset my password if I forget it?.....	39
4.2 Smell Annotator	39
4.2.1 Can I Use Smell Annotator without Signing in?	39
4.2.2 Is the Smell Annotator software compatible with all platforms?	39
4.3 Smell Inspector.....	39
4.3.1 Why is the USB connection not working?.....	39
4.3.2 How do I connect the Smell Inspector to the Smell Annotator?.....	39
4.3.3 The Bluetooth connection is working, but only when the device is connected through USB. Why is this happening?.....	39
4.3.4 What should I do if the Smell Inspector device cannot be turned on?.....	39
4.3.5 Can I use the Smell Inspector with Smell Annotator without a USB connection?	39
4.3.6 Where can I update the Smell Inspector firmware?	39
4.3.7 Do the different devices react to the smell in the same way?.....	40
4.3.8 How should the Smell Inspector device be handled during the measurement?.....	40
4.4 Measurement.....	40
4.4.1 How to take Measurement?	40
4.4.2 What are the temperature and humidity values in the graph?	40
4.4.3 Is it possible to see all the channels in visualization?	40
4.4.4 What are the three states of the measurement?	40
4.4.5 What is the event in the measurement?	41
4.4.6 Can I measure multiple smell measurements one by one without having a delay?	41
4.4.7 Is there any best practice to do the measurement?.....	41
4.4.8 About measurement drifts in the measurement, Is it normal?	41
4.4.9 What do I expect as a response in the measurement graph from the smell measurement?.....	41
4.4.10 What if the measurement environment changed during the measurement?	41
4.4.11 Can other Smells or changing smell environment can affect the actual measurement?	41
4.4.12 Is it possible for two measurements of the same smell substance to have varied graph responses?	42

Technical Manual

4.4.13 How can I export my measurements data?	42
4.4.12 How can I delete a measurement?	42
4.5 Recognize Smell.....	42
4.5.1 What is the Smell Recognition feature, and how does it work?	42
4.5.2 Which smells can I recognize with Smell Inspector/Smell Board device?	42
4.5.3 How accurate is the Smell Recognition feature, and what factors can affect its performance?	42
4.5.4 How can I get a ML model for a specific use case?	43
4.5.5 How can I ensure the accuracy of a ML model for smell recognition?	43
4.5.6 The 'Recognize Smell Line' is appearing in the plot panel with a delay. What could be the reason?..	43
4.5.7 Which smells can I recognize with Smell Inspector?.....	43
4.5.8 Is there a video tutorial available for using the Smell Inspector device to recognize smells?.....	43
4.6 Detectors.....	44
4.6.1 Is there a list of which sensors measure what, such as nitrogen dioxide?	44
4.6.2 Does the sensor return a default value if it doesn't measure anything?	44
4.7 Technical Issues.....	44
4.7.1 Why is the app crashing on my device?	44
4.7.2 Why is my device not detecting the Smell Inspector via Bluetooth connection?.....	44
4.7.3 Why am I getting inaccurate measurements?	44
4.7.4 Why am I unable to update the Smell Inspector firmware?	44
4.8 Other.....	45
4.8.1 Where can I find the privacy policies and the terms of use?	45
4.8.2 How can I get in touch with IT-Support?.....	45
4.8.3 Can we access raw measurements collected by other users or internal SNT measurements?	45
4.8.4 Can you tell me how you use AI and what approach you take, or is that a trade secret?.....	45
5. Operating the Smell Inspector without the Smell Annotator.....	46
5.1 USB Measurements.....	46
5.2 Bluetooth Measurements.....	47
6. Insights of the Measurement	48

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

1. Overview

1.1 Purpose of the Manual

The purpose of this manual is to provide technical information about the Smell Inspector and to guide users through the process of using it effectively. The manual is designed for individuals with different backgrounds and levels of expertise, from developers and scientists to tinkerers. It covers everything from an overview of the Smell Inspector's features to the specific steps for training it to detect and distinguish specific smells. Additionally, the manual provides information about the sensitivity and performance of the Smell Inspector's detectors, as well as details on replacing or maintaining them. Overall, the manual aims to empower users to fully utilize the capabilities of the Smell Inspector and make the most of their experience with this innovative and powerful tool.

1.2 Getting Started

Welcome to the world of electronic olfaction! The Smell Inspector is an advanced tool designed to detect and distinguish specific smells. Whether you are a developer, scientist, or just a curious tinkerer, the Smell Inspector is the perfect tool for anyone working on smart systems. In this manual, you will learn how to get started with the Smell Inspector and start detecting different smells.

1.2.1 Step 1: Unpacking Your Smell Inspector

Upon receiving your Smell Inspector, carefully unpack all the components from the box. Make sure that you have received the following components:

- Smell Inspector
- Smell Annotator software platform
- USB cable for connecting to a computer

1.1.2 Step 2: Installing the Smell Annotator

The Smell Annotator is a software platform that allows you to control, annotate and store measurements of the Smell Inspector, as well as recognize annotated smells. To install the Smell Annotator, simply follow the instructions provided in the software platform.

1.1.3 Step 3: Connecting the Smell Inspector

Connect the Smell Inspector to your computer using the USB cable. Once connected, the Smell Annotator will automatically recognize the Smell Inspector and you are ready to start using the Smell Inspector.

1.1.4 Step 4: Recording Smells

The Smell Annotator software platform allows you to record smells and annotate them. To record a smell, simply open the Smell Annotator and select the "Take a New Smell Measurement" option. Then, point the Smell Inspector towards the source of the smell, and the Smell Annotator will start recording the smell measurement. Once the measurement is complete, annotate the smell by providing a name and description.

1.1.5 Step 5: Recognizing Smells

The Smell Annotator software platform comes with pre-trained machine learning models that you can use to recognize annotated smells. To recognize a smell, simply select the "Recognize Smell" option in the Smell Annotator, select a ML Model, point the Smell Inspector towards the source of the smell, and the Smell Annotator will use the pre-trained models to recognize the smell.

That's it! You are now ready to start detecting smells with the Smell Inspector. If you have any questions or need further assistance, please consult the manual, or reach out to the support team. Enjoy your journey to the world of electronic olfaction!

1.3 Product Overview

This section provides an overview of the Smell Inspector, including its features, capabilities, and the ways it can be used. The Smell Inspector is a developer kit and ready-to-use device in one, designed for anyone working on smart systems, including developers, scientists, and tinkerers. The device generates digital scent fingerprints and be trained to detect and distinguish specific smells. The Smell Inspector contains four Smell iX16 chips and humidity and temperature sensors and can detect a wide range of gases and smells, depending on their concentration at the measurement spot.

1.3.1 Smell Inspector

The Smell Inspector is 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. It can be connected to a PC, tablet, or smartphone, 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



Figure 1. Smell Inspector device

Installing the batteries: in order to use Smell Inspector without USB cable open the device housing, place the new batteries (AAA, not included) into the battery compartment, notice the correct battery polarity as depicted on the compartment when inserting. Never leave a weak or dead battery in Smell Inspector. Even a leakproof battery can leak damaging chemicals. When you are not going to use Smell Inspector for a week or more, remove the batteries. Please dispose of old batteries at a council collection point or return them to a local shop at no cost. The disposal of domestic refuse is strictly forbidden according to the Battery Regulations.

1.3.2 Smell Annotator

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

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

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

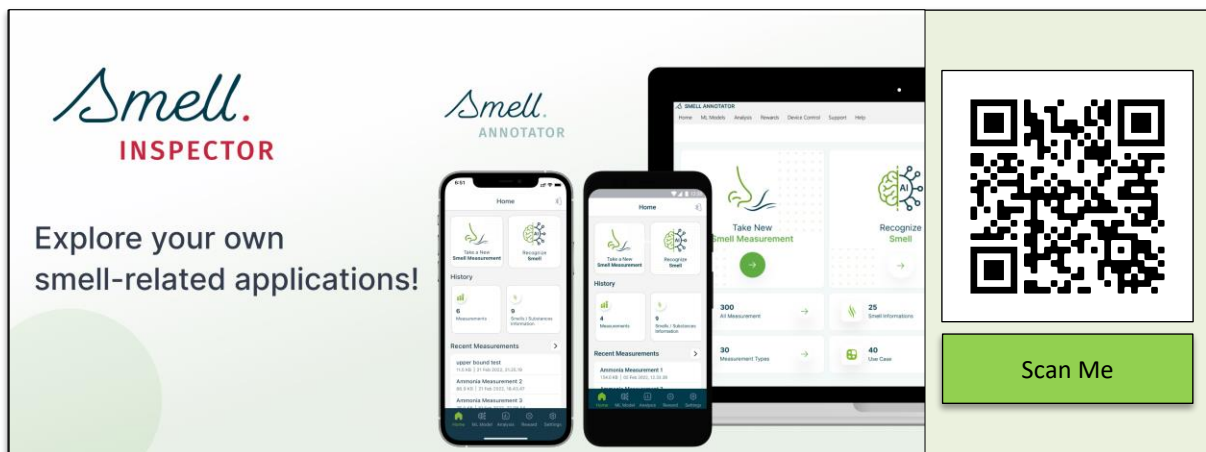


Figure 2. Smell Annotator download QR Code

System Requirement

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

Processor	Intel Core / AMD CPU
RAM	4 GB
Available Disk Space	800 MB
OS	Windows 10 and 11 supported

From the desktop app version $\geq 1.1.1$, no need to perform driver installation manually.

For the desktop app version $< 1.1.1$.

Before you start the program, please first install the sensor drivers (see below).

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.

- For Android Device: V6.0 and above
- For iOS Device: V11.0 and above

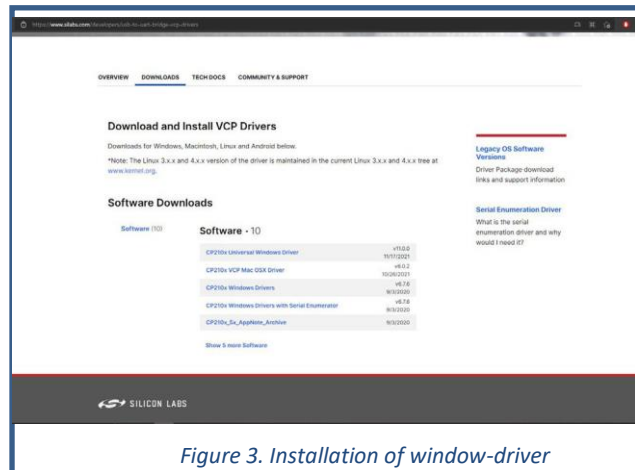


Figure 3. Installation of window-driver

1.4 Device Control

You can enable power saving mode anytime by pressing the power button for a long period (more than 4 seconds). Once the Smell Inspector is in power saving mode, you need to press the POWER button again for a long duration of time to bring it back into normal operating mode. To connect Smell Inspector to your mobile device via Bluetooth press the Fn button for a long period. To put a timestamp for an event on the measurements shortly press the POWER button (less than 2 seconds). The Smell Inspector operating mode is visualized with two LEDs. Both the blue and red LED will be off in power-saving mode and the connection of the Smell Inspector to the other devices will be terminated.

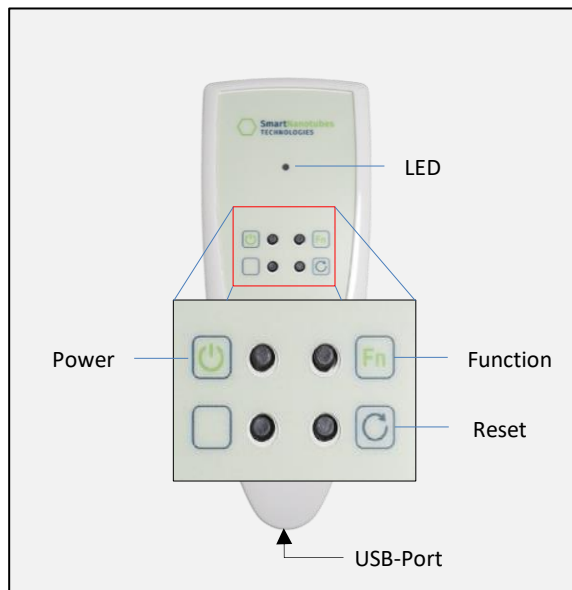


Figure 4. Smell Inspector Overview

Device control:

- Buttons: used for device operation
- LED: device status and button functions
- USB Port: USB Micro-B port for power and communication

1.4.1 Button Operation

Device Button	Press	Meaning
Power	long-press (>4 sec.)	Sleeping mode ON/OFF
	short press (<2 sec. in-running measurement)	Add Event timestamp
Function	long-press (>4 sec.)	Bluetooth pairing mode enable / Bluetooth turn-off
Reset	short press	Resetting the device

Table 1. Button Operation

1.4.2 LED Readings

LED	State	Meaning
OFF	-	Powered Off / Power Saving Mode
ON	Continues RED	USB operating Mode
ON	Blinking BLUE	Bluetooth pairing mode
ON	Continues BLUE	Device Connected via Bluetooth

Table 2. LED Readings

1.5 Terminology and Meanings

Name	Meaning
Take a New Smell Measurement	measurement for smell/gas digitization and annotation
Recognize Smell	measurement for smell recognition with AI algorithms
Measurement	capturing and digitalization of a smell
Smell/Substance	It is the actual Smell or Substance (gas, vapor, or smelly substance) that is being measured in the measurement
Use Case	It is the specific goal for which the measurement is being taken (e.g., kitchen, production, WC, etc.)
Event	The event is a change in the measurement state (start of exposure, end of exposure)
Measurement Setup	Short description of a setup or environment in which the measurement is taken
Local (Measurements)	Incomplete offline measurements which must be saved later adding all relevant Smell/Substance information when connected to internet
Cloud (Measurements)	Complete measurements saved in the cloud

Table 3. Terminology

For the correct work of ML algorithms used for smell recognition, the new smell measurements should be collected and properly annotated. To a proper annotation of new measurements belongs the information about the measured smell or substance (it must be the same for the same substance/smell) and the information on events (start and end of exposure) during the measurement. In general, measurement is divided into three states: first stabilization in a usual condition before exposure, the exposure with the target smell/gas, and recovery and stabilization after the end of exposure.

1.5.1 Smell / Substance Information

Information on the smell and the measurement conditions

Please always provide information on the smell or substance you measure. If the same smell is measured in different conditions, this variability can be also included here. All this information will be used for ML algorithms, so for the same smells and the same conditions, the same annotation must be used for all repeating measurements.

1.5.2 Events

Event is the change of the measurement state.

A short smell/gas measurement is usually divided into three states. First, you begin the measurement when the device is exposed to a normal environment free of smell or substances. Once the detectors are stabilized in the current environment, the next measurement state will be when the detectors are exposed to the target smell or substance. The moment when the previous state "stabilization" is affected by exposing a smell or substance is referred to as an "**Event**", you may name it "**Start of exposure**".

The third state is when exposing the device to the smell is terminated, i.e., the Smell Inspector device is taken away from the smell or the substance, smell or gas source is removed from the Smell Inspector. This moment is referred to as an "**Event**" as well and can be named as "**End of exposure**". When the device is no longer exposed to a smell or substance and is in the same environment as before the exposure, the detectors are in a recovery mode. Depending on the smell or substance being exposed to, the recovery time may take from a minute to several minutes and in some cases up to an hour to return

to a stable state. It is recommended to wait for the recovery of at least down to ca. 10% of the response before taking the next measurement.

The measurement contains two consecutive Events, considering the standard short measurement. Dependent on Measurement Type and Use Case the event can be different. You can also name your Events accordingly. An event is not limited to the Start of Exposure and End of Exposure. An event is related to a change in measurement state, which can also be related to the measurement environment. For example, the normal measurement might be affected by a sudden change in airflow into the device inlet. Ongoing measurement of this change is considered and should be annotated as an "Event".

1.5.3 Local (Offline measurements)

The Smell Annotator is only fully functional when connected to the internet. To support the user in taking smell measurements offline, the application allows the user to take measurements offline, and the data is saved locally in the application only (CSV format). In offline measurement, it is not possible to add any additional information, only the basic information 'name' and 'comment' can be saved. These offline measurements are considered incomplete and must be saved with Smell/Substance Information once the application is connected to the internet.

1.5.4 Cloud (Online measurements)

Cloud measurements will be saved to the system cloud on your account. By logging in to your user account, you can access all these measurements anywhere using the Smell Annotator application.

2. Smell Inspector

Dimensions	166 x 64 x 31 mm / 6.54 x 2.52 x 1.22 inch (LxWxH)
Power consumption	max. 0.28 W
Weight	130 g / 0.29 lb
Materials	two PCBs, four Smell iX16 chips, housing
Read-out time	all 64 channels every 1.8 s
Read-out format	ASCII
Serial interface	USB Micro-B cable plug
Power supply	via USB Micro-B or batteries
Batteries	2 AAA (not included)
Temperature range	from +5°C to +40 °C
Pressure	atmospheric pressure

Table 4. Technical Specification - Smell Inspector

2.1 Modes of Operation

The device has three operational modes:

2.1.1 USB Operating Mode

As soon as the Smell Inspector is connected to a PC with a USB cable, it starts sending data via USB. In this mode, the red LED will always remain lit.

2.1.2 Bluetooth Operating Mode

In this mode the Smell Inspector should be powered with batteries or with a power bank for smartphones via a USB cable. Switch on the device (Power button), enable pairing mode (Fn button). The Smell Inspector will wait until it establishes a connection with your mobile device using Smell Annotator app. During this period the blue LED will blink. When the connection is established, the Smell Inspector will begin transmitting data to the mobile application and the blue LED will now glow.

2.1.3 Power Saving Mode

To extend the device batteries life. In this mode the LEDs are off. If the Smell Inspector is powered with batteries, the Smell Inspector will go in the power saving mode if no connection is established within 120 seconds.

Note: When using the batteries and USB cable to operate the Smell Inspector device, it might be the case that when you plug in the USB cable, the red LED will not turn ON. In this case, long-press (> 4 sec) the power button to turn ON the device.

2.2 Things to Keep in Mind

To change the detectors or to insert the batteries please open the housing of the device. Do not touch the surface of the detectors with your fingers or some object unless you are replacing it with the new one. It is not recommended to blow directly into the device inlet.



Please notice that it is important to be careful when inserting new detectors into the detector sockets: no excessive force has to be applied and no bending of detectors is allowed. Do not touch the surface of the detectors as a grip to hold it. This may cause scratches on the detector sensitive surface and lead to the irreversible damage of the detector.

2.2.1 Smell Inspector Overview

The Smell Inspector is a comprehensive tool for smart systems development. It is a developer kit and a ready-to-use device in one, designed for use by developers, scientists, and tinkerers alike. The Smell Inspector can detect and distinguish specific smells through training. It is suited for manufacturers who aim to monitor their production environment and product quality.

2.2.2 Smell Inspector Operation

The Smell Inspector consists of four Smell iX16 detector chips, humidity sensors, and temperature sensors. It uses an array of multiple independent gas detectors to create digital scent fingerprints, updating these fingerprints every 1.8 seconds. The identification of smells is based on pattern recognition, where each scent produces a unique pattern of signals from the sensor array. To utilize the Smell Inspector for gas/smell recognition, a machine learning (ML) model must be used with enough annotated smell measurements processed through an ML algorithm. This can be achieved through the Smell Annotator software platform.

2.2.3 Detectable Gases and Smells

The Smell Inspector can detect a wide range of gases, vapors, and smells, the sensitivity of which depends mainly on their concentration/intensity at the measurement location. Some tested gases and vapors are ammonia, nitrogen oxides, phosphine, carbon dioxide, hydrogen sulfide, hydrogen peroxide, ethanol, acetone, isopropanol, toluene, formaldehyde, 2,6-dimethoxy-phenol, 2 methoxy-4-vinyl phenol, guaiacol, eugenol, and various scents such as coffee, tea, wine, lemon juice, onions, garlic, bananas, oranges, potatoes, meat, and fish (a selected list).

2.2.4 Gas Detector Sensitivity

The sensitivity of the gas detectors has been benchmarked against standard test cases, with the limit of detection below 80 ppb for ammonia, nitrogen oxide, phosphine, and hydrogen sulfide.

2.2.5 Detector Replacement

The detectors are designed for ZIF sockets, allowing for easy replacement of the detector chip if necessary.

2.2.6 Detector Cleaning

Cleaning of the detector chip after contact with particles or gas molecules is not required and not recommended.

2.2.7 Smell Inspector Training

The Smell Inspector can be trained to detect specific smells measured using the Smell Annotator software, which allows for control, annotation, and storage of smell measurements as well as recognition of annotated smells.

3. Process Steps

3.1 Setup an Account

Sign up and set up an account for Smell Annotator. Next, Sign-In to Smell Annotator.

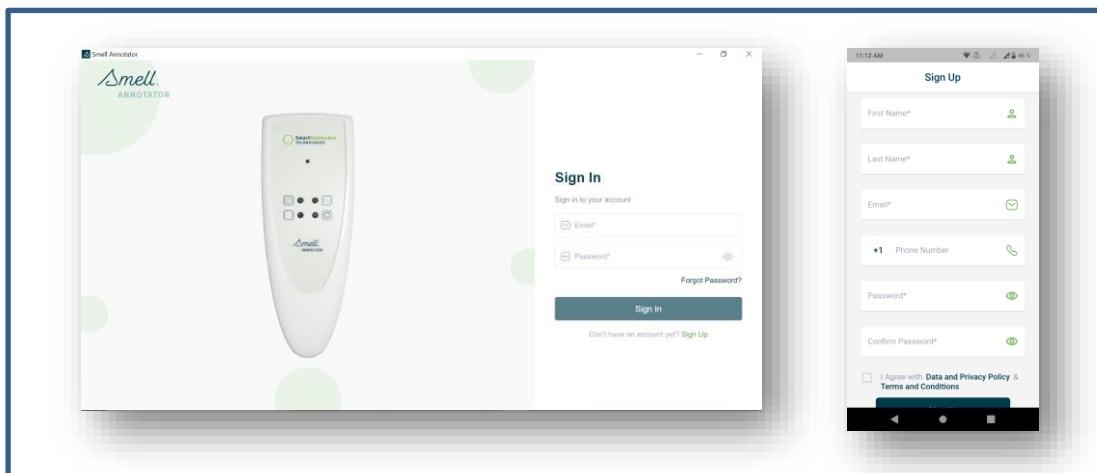
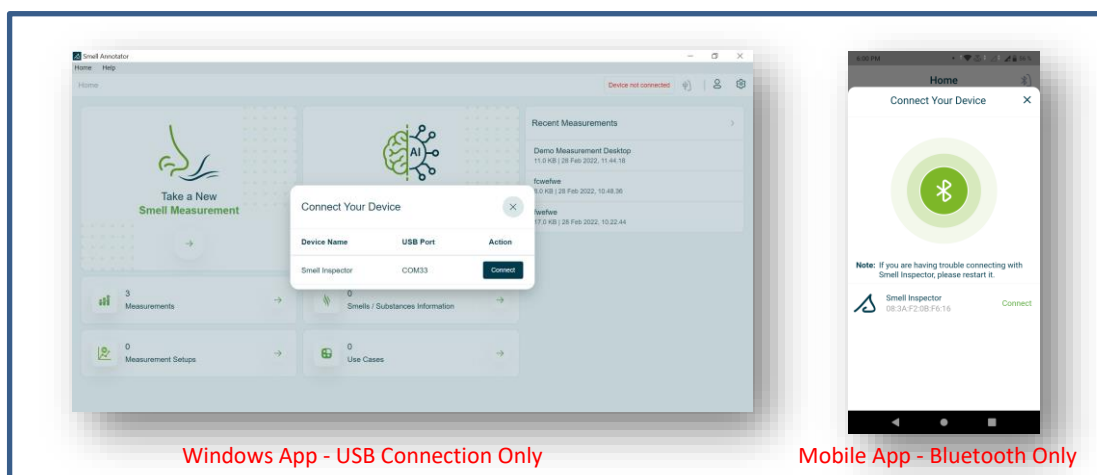


Figure 5. Setup an account for Smell Annotator

3.2 Connection to Smell Annotator App

Smell measurements can be taken using the Smell Inspector together with the Smell Annotator app. To do so, the Smell Inspector device must be connected to the Smell Annotator app. The device can be connected to Smell Annotator mobile application (Android, iOS) via Bluetooth or to desktop application (Windows) via USB connection.



Windows App - USB Connection Only

Mobile App - Bluetooth Only

Figure 6. Connect the Smell Inspector

- USB Connection

Connect the Smell Inspector via USB to Desktop app.

- Bluetooth Connection

To connect the Smell Inspector to the Smell Annotator Mobile app, follow these steps:

1. Launch the Smell Annotator Mobile app on your smartphone or tablet.
2. Enable Bluetooth pairing mode on the Smell Inspector device: Press and hold the FN button for more than 4 seconds. The blue LED on the Smell Inspector device will start to

3. In the app, go to the settings menu and select "Bluetooth Devices."
4. Look for "Smell Inspector" in the list of available Bluetooth devices and select it.
5. Once the connection is established, the blue light on the Smell Inspector device will stop blinking and stay solid. You are now ready to start collecting and annotating scent measurements.
6. To disconnect the Smell Inspector from the Smell Annotator Mobile app, simply go back to the settings menu and select "Disconnect." The blue light on the Smell Inspector device will start blinking again, indicating that it is in pairing mode.

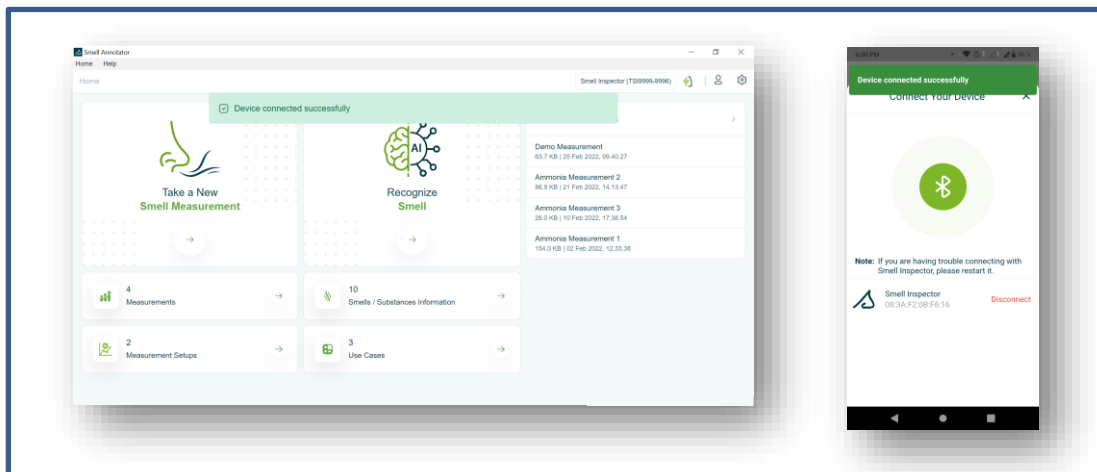


Figure 7. Connection to Smell Annotator

Once the Smell Inspector is connected, the connection status is shown in the toolbar and notification will pop up.

3.3 Smell Measurement for Annotation

3.3.1 Step 1: Start New Smell Measurement

The device is ready for taking measurements; however, it is strongly recommended to wait about 20 min for the detector stabilization in a new environment and the air flow. Click on "Take a New Smell Measurement" to start the measurement as shown in Figure 8.

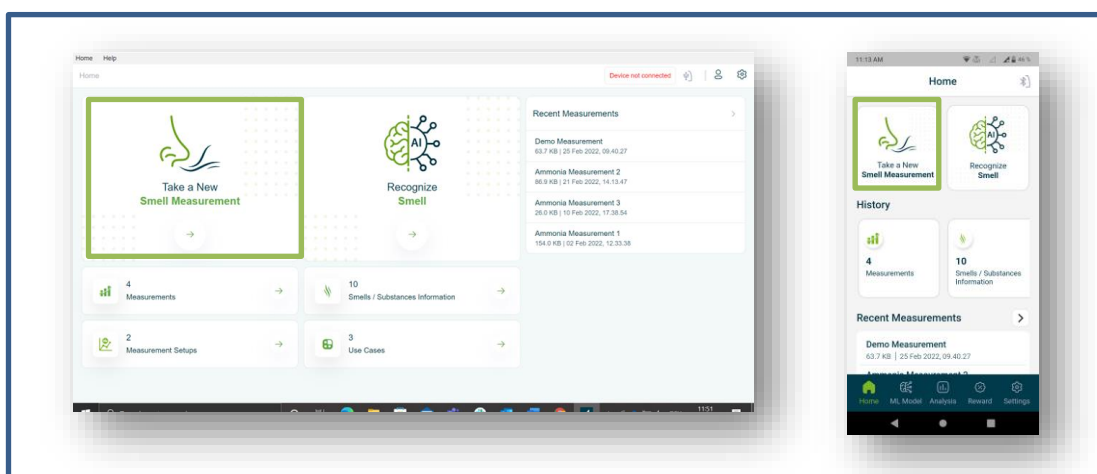


Figure 8. "Take a New Smell Measurement"

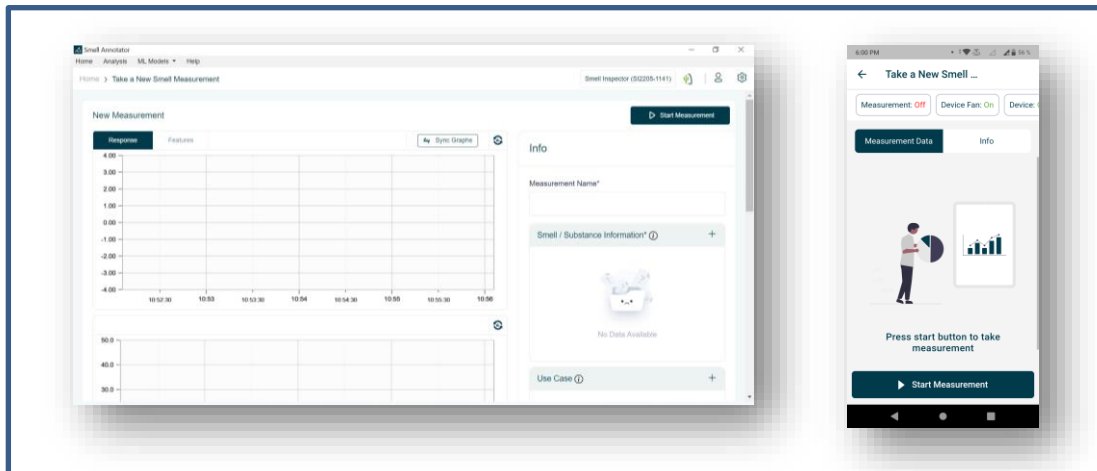


Figure 9. "Start Smell Measurement"

Once you click on "Start Measurement" it will take few seconds for Initialization process.

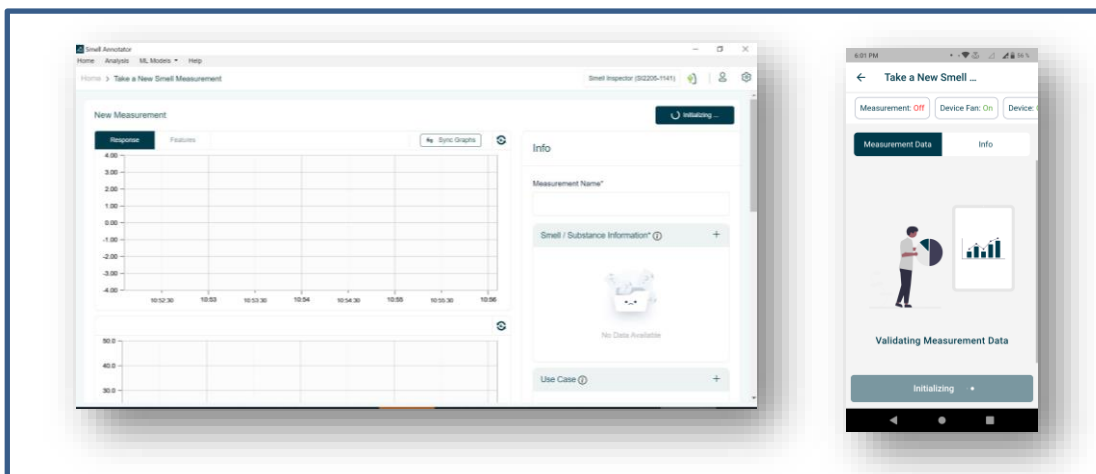


Figure 10. Initialization of a new measurement

Measurement started: the graph shows the averaged real-time smell sensor response in the upper panel (change in %) and temperature and humidity values (in °C and %) in the lower panel.

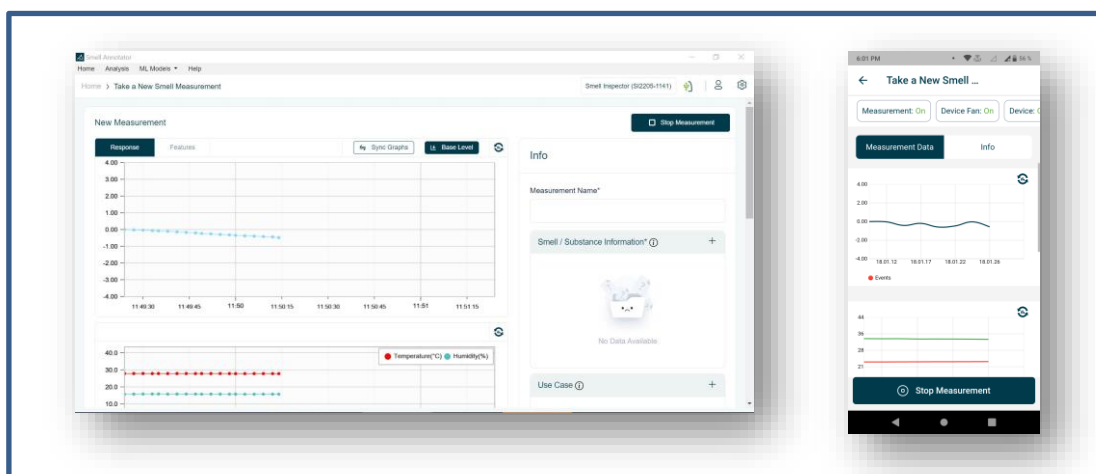


Figure 11. Real time visualization of the measurement

3.3.2 Step 2: Add Measurement Information

Please add necessary Information about Measurement Name (*), Smell/Substance (*), Use Case, Measurement Setup.

(*): Marked as necessary to save the measurement.

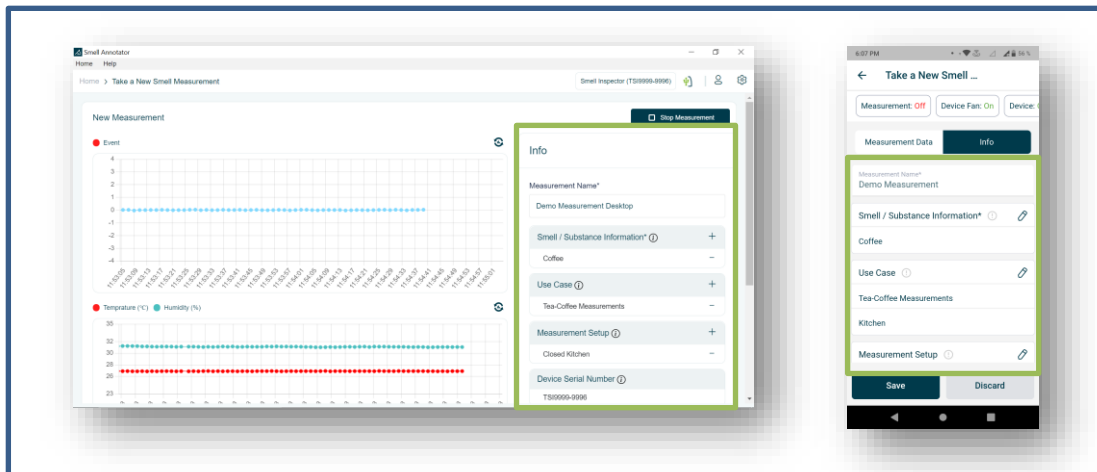


Figure 12. Add Information

3.3.3 Step 3: Stop and Save Measurement

To save the measurement, first click 'Stop Measurement' and then 'Save Measurement'.

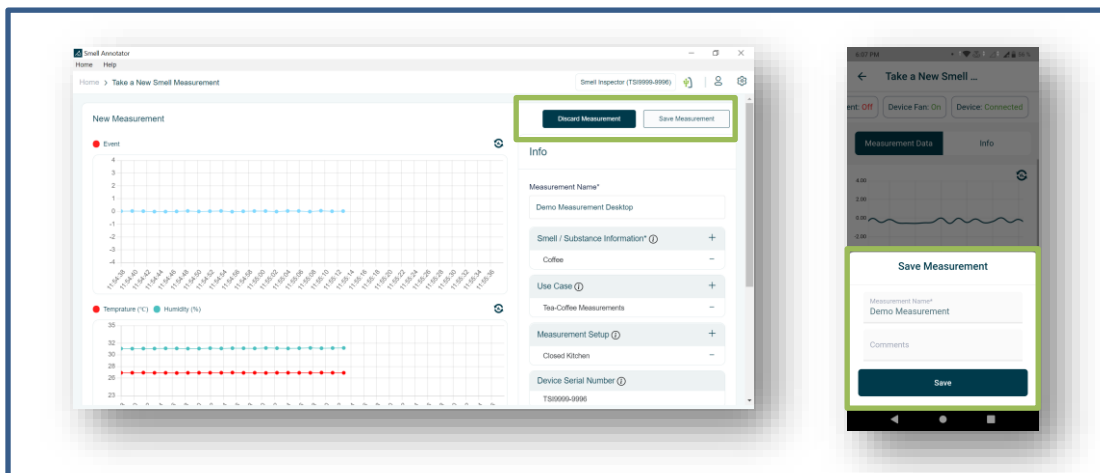


Figure 13. Stop and Save Measurement

3.3.4 Step 4: View saved measurement in the Measurement List

When a measurement is saved, the Measurement listing screen appears, with a successful message at the top as shown in Figure 14.

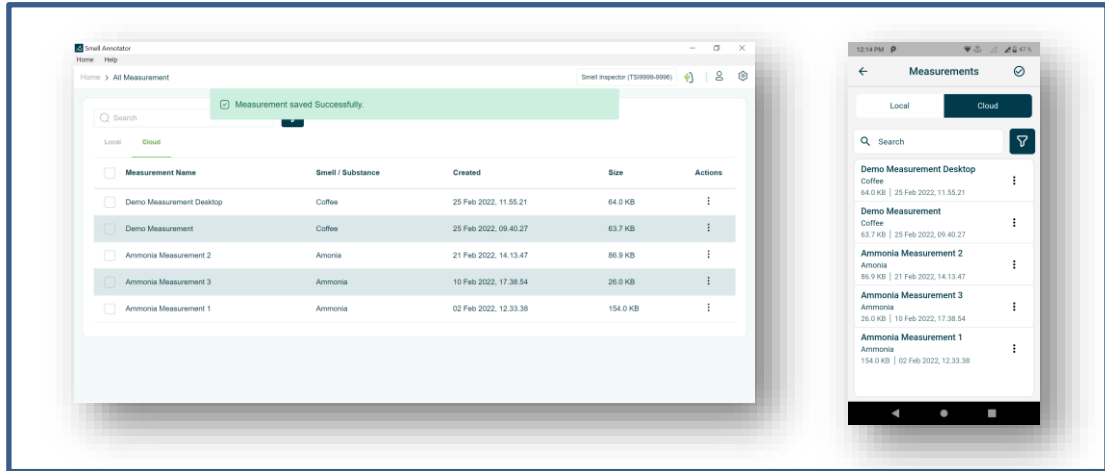


Figure 14. View in the Measurement List

3.4 Recognize Smell Measurement

Introduction

Recognize Smell is a feature that uses machine learning (ML) models to classify and identify different smells or substances. It is trained on a large dataset of smell samples, allowing it to learn patterns and characteristics associated with each smell. This technology provides a fast and reliable way of identifying various smells, making it useful for various applications, such as air quality monitoring, product quality control, fire prevention, safety, and environmental monitoring.

ML Model

ML model is created with a ML algorithm that uses large amounts of data to perform a specific task, such as recognizing smells. The ML model is trained on a large dataset of collected smell measurements, containing annotations (information on smell in the air, time of exposure). The ML model then uses this information to make real-time predictions about the smell it is currently presented with.

Using the Recognize Smell Feature

The Recognize Smell feature is activated when the Smell Inspector is exposed to a particular smell and the corresponding ML model is selected. The sensor response signals are processed by the ML model, which provides real-time predictions of the present smell. The recognized smells are visualized as a solid line, representing the current smell or substance in the air, with each specific smell displayed in a unique color. Normal air (no smell) is represented by a grey color. Additionally, the feature allows you to recognize smells from previously saved measurement data.

Addressing Incorrect Recognition

In certain instances, the Recognize Smell feature may provide incorrect predictions about a smell. This can occur due to various factors, such as environmental changes, introduction of new smell profiles not present in the training data, unstable initial baselines, or interference from other substances in the environment.

Providing Corrected Feedback

To improve the accuracy of the Recognize Smell feature, it is crucial to provide correct smell information when saving measurement data. This corrected information is utilized to train the ML model and enhance its smell recognition accuracy over time.

Factors Affecting Smell Recognition

Several factors can influence the accuracy and performance of smell recognition in the Recognize Smell feature. These factors include:

1. Training Data and Model Accuracy:
The quality and quantity of the smell measurement data used to train the machine learning model are crucial for accuracy. The model relies on a diverse and representative dataset to generalize well to different scent profiles. The more comprehensive and varied the training data, the more accurate the predictions will be. However, it is important to note that the accuracy of the model is limited to the smells it has been specifically trained to recognize.
2. Environmental Conditions:
Environmental factors play a significant role in the performance of the Smell Recognition feature. Variables such as temperature, humidity, air quality, and the presence of other Smell can affect the accuracy of smell recognition. Therefore, using the feature in controlled and stable environments helps ensure more reliable results.
3. Customer-Provided Information:

When incorporating customer measurements, there can be challenges in accurately determining the substance being measured. Customers may provide information that is incomplete or incorrectly labelled, which can affect the accuracy of substance recognition. For example, different customers may measure various forms of coffee but label them all as "Coffee," making it difficult to determine the exact substance characteristics.

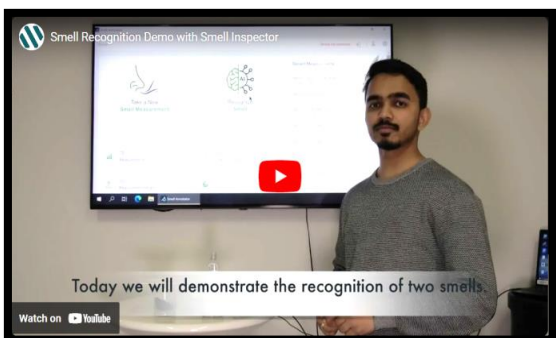
4. Hidden Parameters and Sample Variations:

Certain hidden parameters can influence the smell of a substance, which may not be immediately recognizable or understood. Factors such as exact substance composition of complex smells, exposure methods, or environmental conditions can contribute to variations in scent profiles. Even within the same substance category, there can be differences in smell due to sample variations.

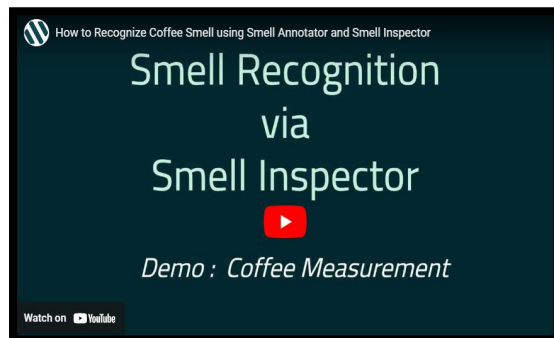
Improving Accuracy and Performance

The Smell Recognition feature operates by training machine learning models on a dataset of smell samples (also called Smell Measurements). However, the accuracy and performance of the feature can be influenced by factors such as the quality of training data, environmental conditions, user/customer-provided information, hidden parameters, and sample variations. Ongoing research and development efforts are focused on improving accuracy and addressing these challenges. Customer feedback and collaboration play a crucial role in enhancing the performance and reliability of the Smell Recognition feature.

Video Guide:



Smell Recognition Demo with Smell Inspector
https://youtu.be/vpiNmES_G0s



This is a descriptive video how to use the Recognize Smell feature in Smell Annotator
<https://youtu.be/g9WBvZgEAdU>

To use Recognize Smell feature, please follow the given steps.

3.4.1 Step1: Start Recognize Smell Measurement

Once device is ready for taking measurement, click on 'Recognize Smell' as shown in Figure 15. It is

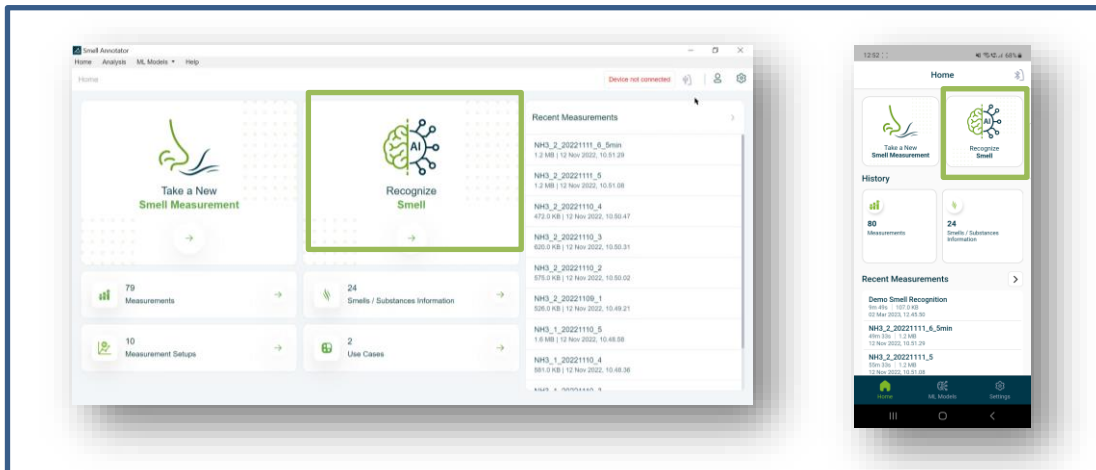


Figure 15. "Recognize Smell"

strongly recommended to wait about 20 min for the detector stabilization in a new environment and the air flow.

3.4.2 Step 2: Select ML Model

Once you click "Recognize Smell", following screen will appear, see Figure 16.

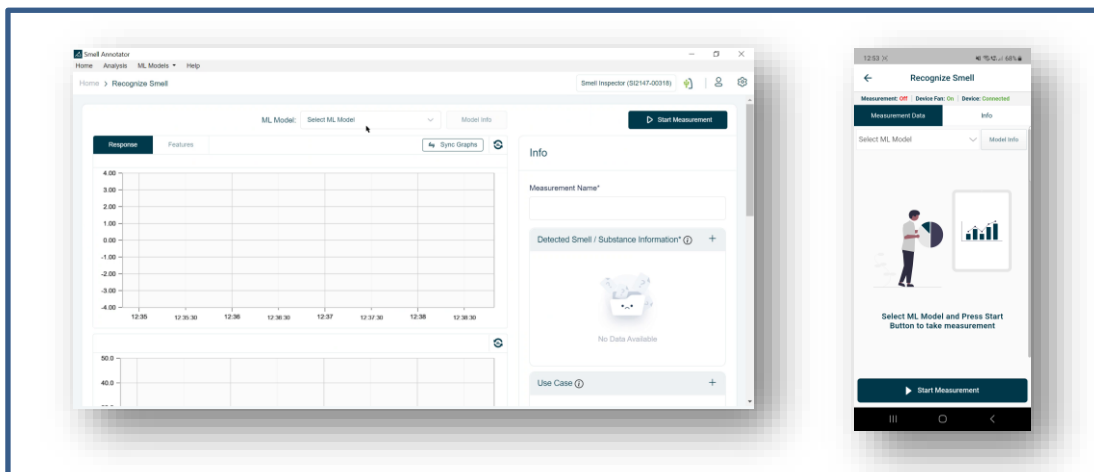


Figure 16. first step: Selection of ML Model

Locate the ML model and choose the appropriate model from the drop-down menu for Recognition. The chosen ML model should contain smells/substances you want to recognize. A short description of the chosen model can be seen in Model Info.

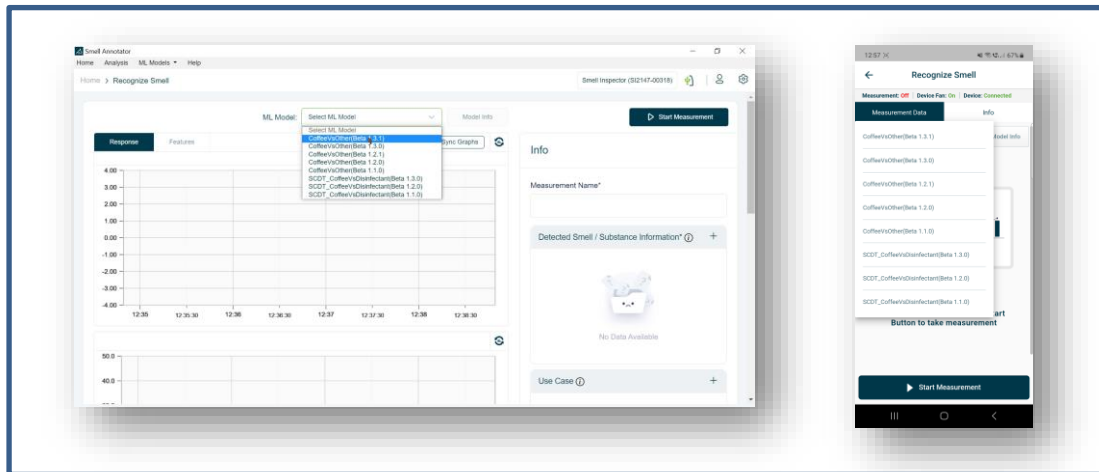


Figure 17. Selected ML model

3.4.3 Step 3: Start Measurement

Once, the model is selected, click on “Start Measurement”.

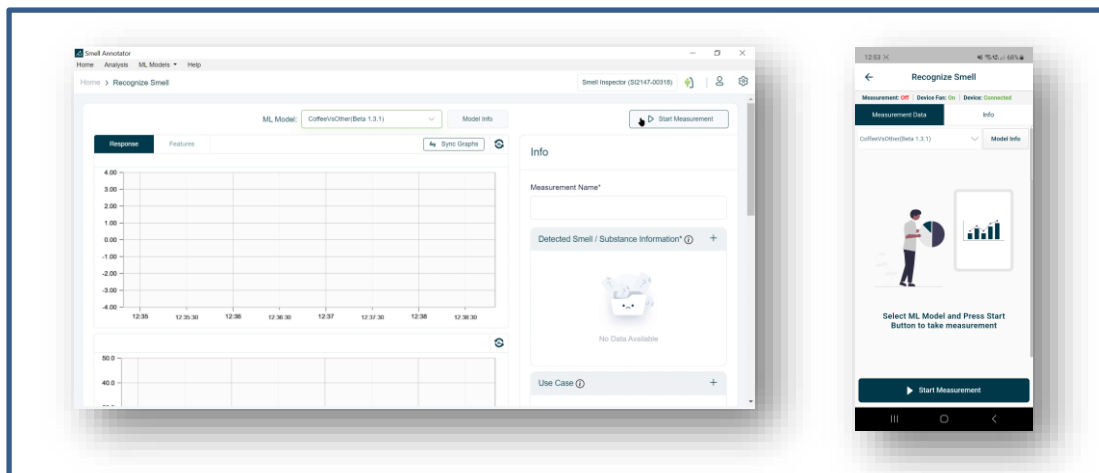


Figure 18. Starting Recognize Small Measurement

Once you click on “Start Measurement” it will take few seconds for Initialization process.

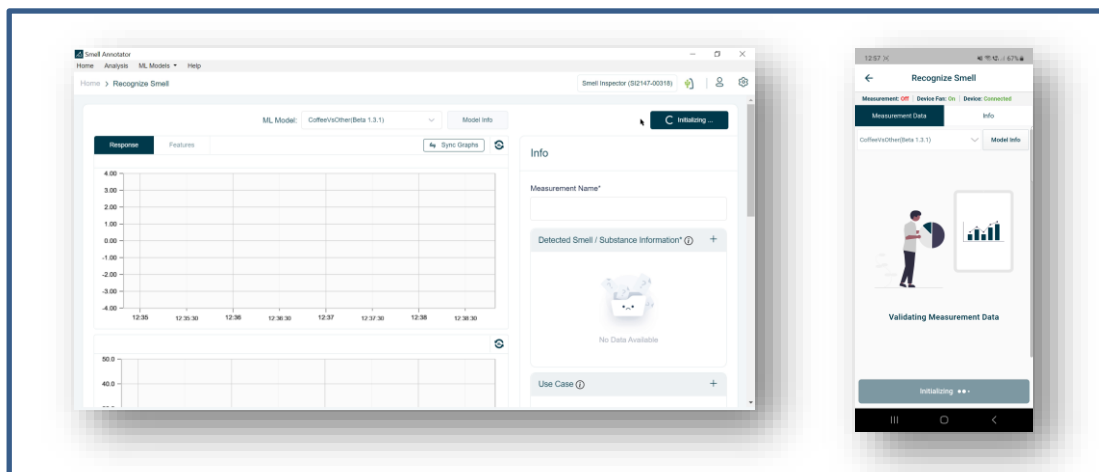


Figure 19. Measurement Initialization

3.4.4 Step 4: Measurement Started – Initial Stabilization

After initialization process, Measurement will start. Normal ‘sky blue line’ will appear in Response

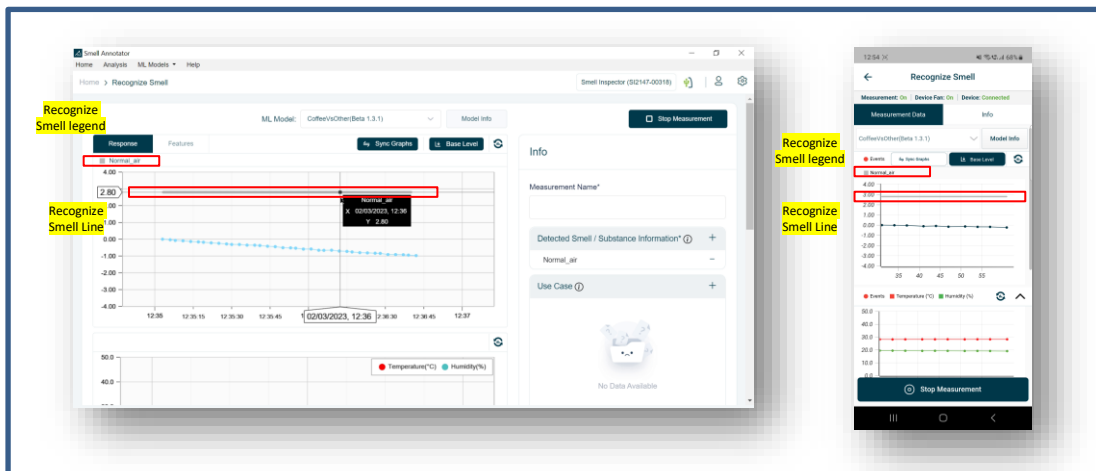


Figure 20. Initial Stabilization, Smell Recognition: “Normal Air”

graph. The 'Recognize Smell Line' is a straight colour line which represents Recognize Smell from selected ML model (i.e., CoffeeVsOther (Beta1.3.1)). Figure 20 shows a Recognize Smell Line that is 'Grey' in colour. The grey colour represents 'Normal air,' as seen in the 'Recognize Smell Legend'.

This is Initial state of the measurement.

3.4.5 Step 5: Expose Device to Smell/ Substance

When you are prepared, expose the Smell Inspector device to the Smell or Substance you want to recognize.

Note: Please keep in mind that the selected model can only predict/recognize smells for which it has been trained. Refer to the 'Model Info' section for a list of smells/substances that the model can correctly identify. It is advised to register an event titled "Start Exposure" to document the start of exposure procedure accurately. Precise event data can be useful for improving the ML model accuracy in future.

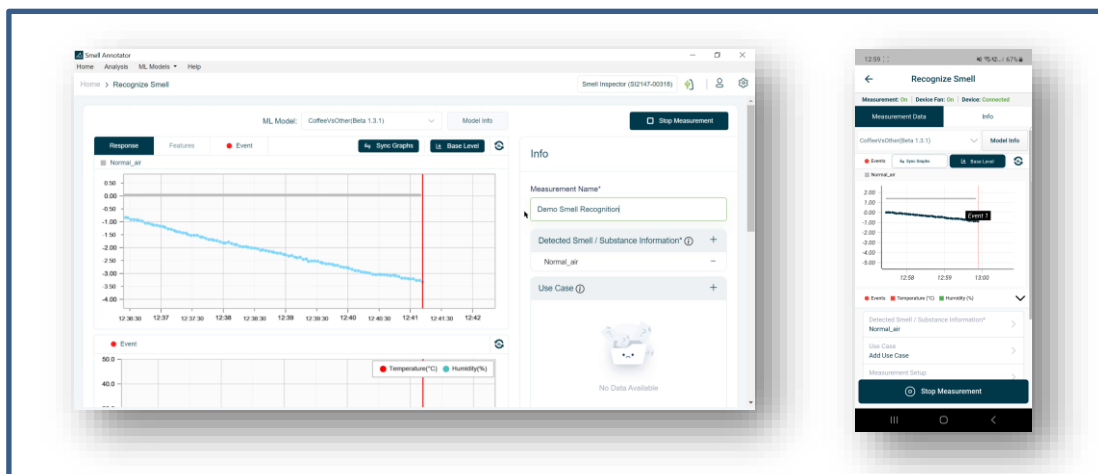


Figure 21. Start of Exposure, Add Event information for Reference “Start Exposure.”

When an event is registered, a red vertical line appears on the screen.

3.4.6 Step 6: Expose Device to Smell/ Substance

Upon exposure of the device to the targeted smell or substance, the selected ML model commences the process of predicting or recognizing the smell. The recognition process may take a few moments to accurately detect the smell. For our experiment, we have opted for the 'CoffeeVsOther (Beta 1.3.1)' model, specifically trained to recognize coffee scent.

As depicted in Figure 22, the colour of the Recognized Smell Line changed due to the exposure of the coffee aroma. Initially, the blue line represents 'Other' smell, followed by a red line representing 'Coffee' scent. Due to the time required for accurate prediction, an initial short incorrect prediction may be observed. This is normal behaviour from ML model.

When the ML model recognizes a smell, the smell is automatically assigned and added to the Smell/Substance information list.

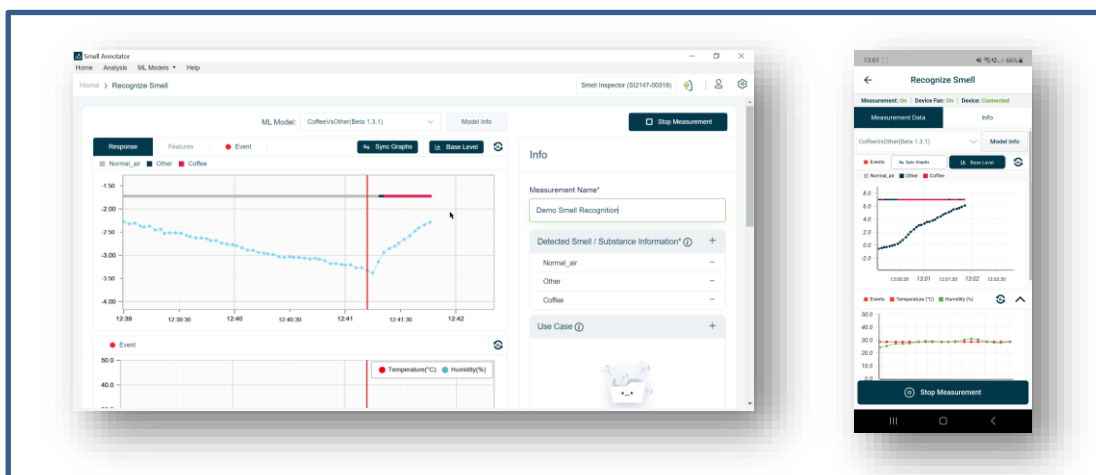


Figure 22. Smell Recognition: "Coffee"

3.4.7 Step 7: End Exposure

Once smell inspector device is exposed to smell, to end the exposure take the device and target smell away from each other. It is advised to mark an event titled "End Exposure" to document the end of exposure procedure accurately. Precise event data can be useful for improving the ML model accuracy in future.

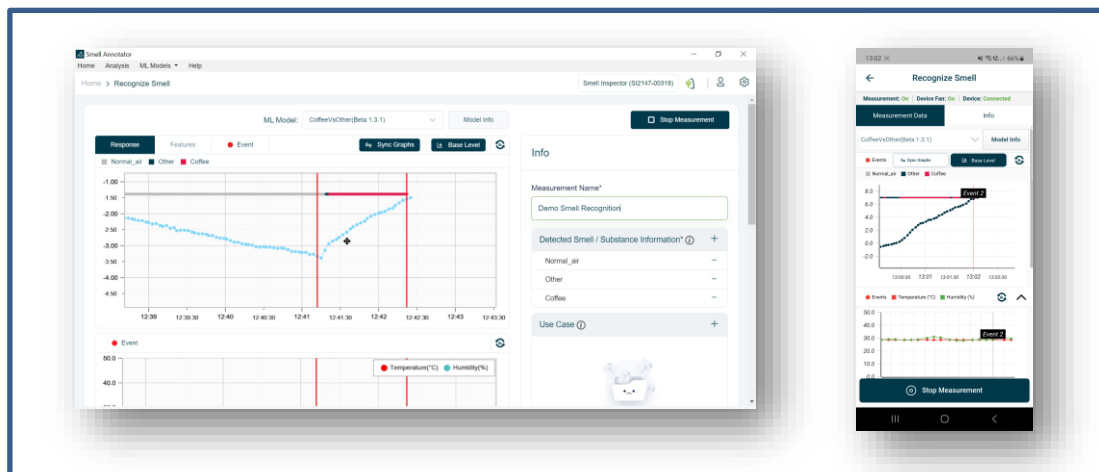


Figure 23. End of Exposure, Add Event information for Reference "End Exposure"

After a few moments, the model recognizes the end of the exposure and the Recognize Smell Line turns grey, indicating 'Normal air'.

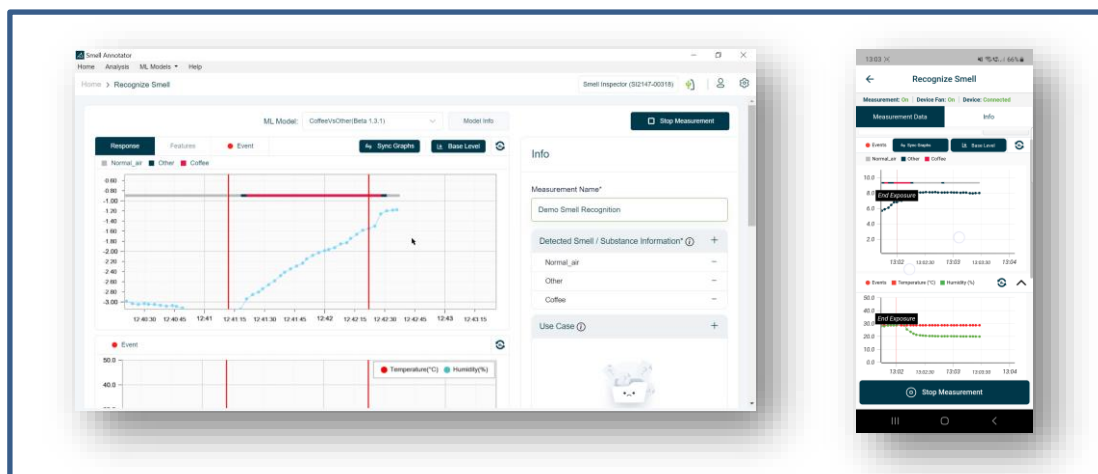


Figure 24. Smell Recognition: "Normal Air"

3.4.8 Step 8: Correct Event name for better reference

When events are marked by shortly pushing the Power button, their names are automatically incremented in the following order: Event1, Event2, etc. If the event name has to be corrected, you may edit it as shown in figure 25 and figure 26.

Correct Events Names:

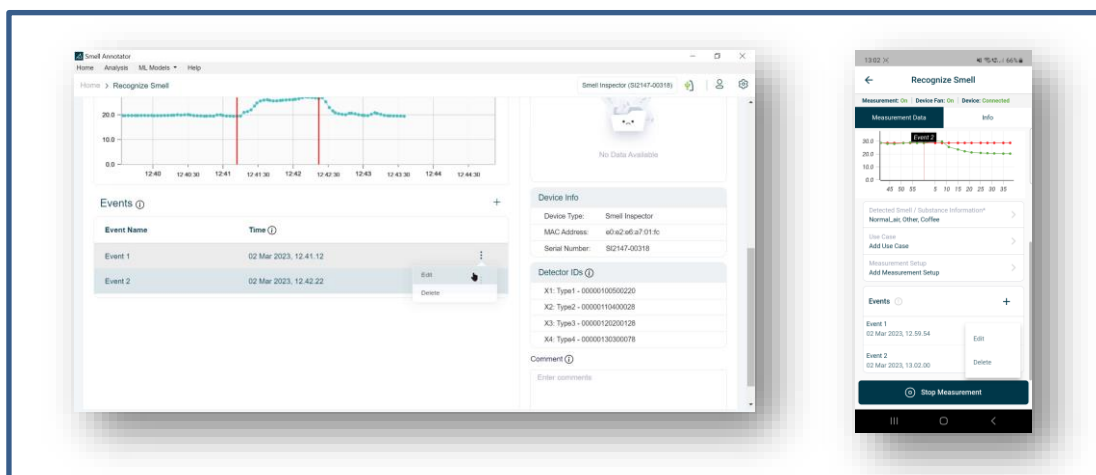


Figure 25. Correct Event name for better reference

Corrected Event Names:

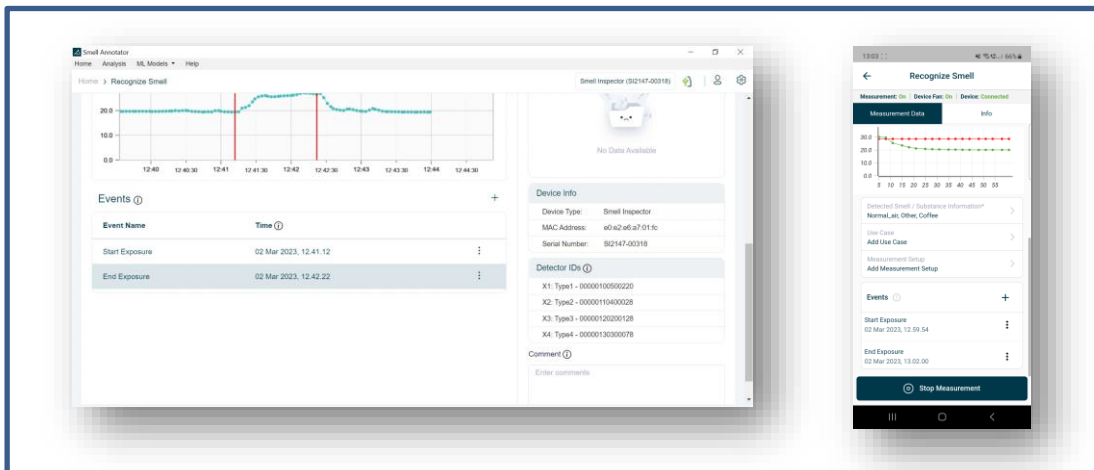


Figure 26. Changed Event Names

3.4.9 Step 9: Stop Measurement

Once measurement is completed, click on 'Stop Measurement' as shown in figure 27.

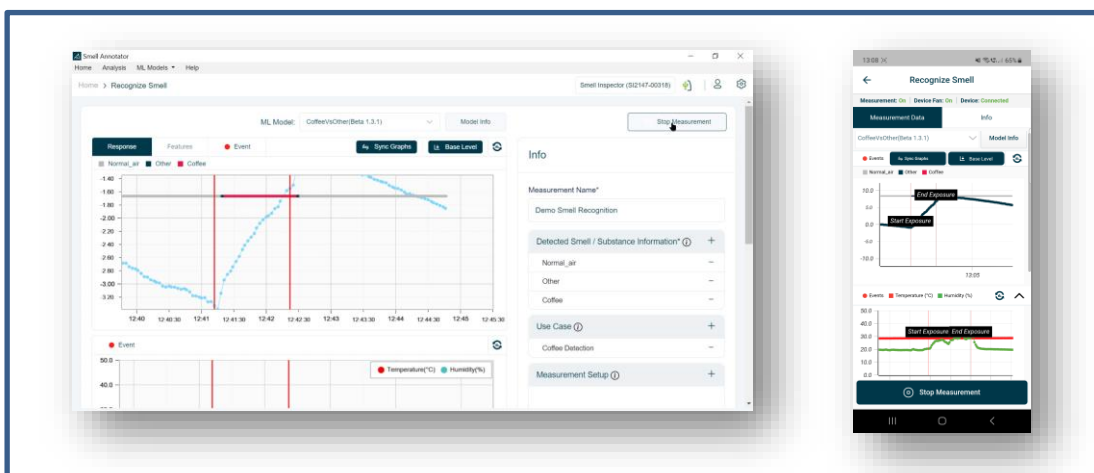


Figure 27. Stop Measurement

3.4.10 Step 10: Save Measurement

You may also correct the Smell Information before this step by removing incorrectly detected smells from the list. To save the measurement, click 'Save Measurement' after clicking 'Stop Measurement'.

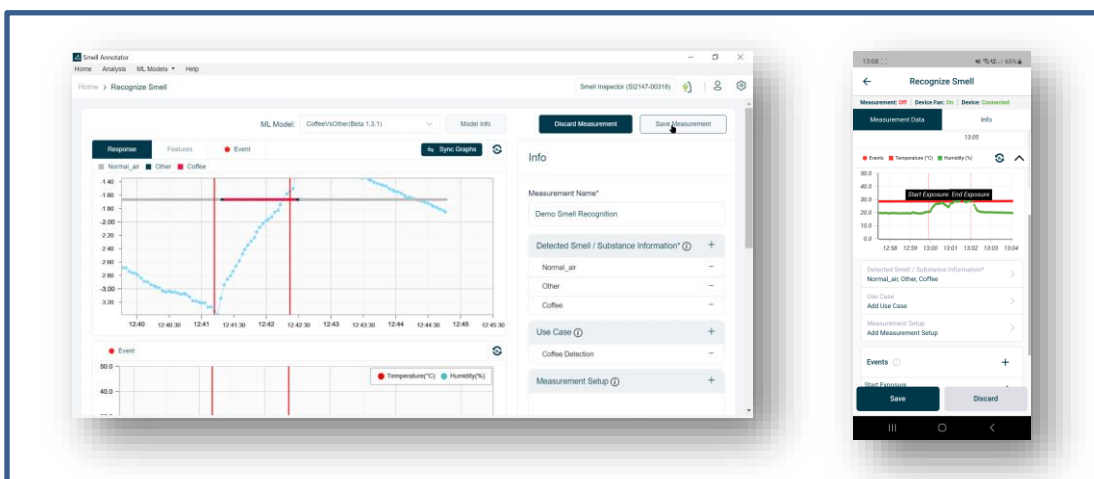


Figure 28. Save Measurement

Save Measurement popup will appear in the screen. In case the ML model recognized the smell incorrectly, the Incorrect Smell will automatically be assigned and added in the Smell/Substance information list. Make sure the Smell Information is correct while saving the measurement.

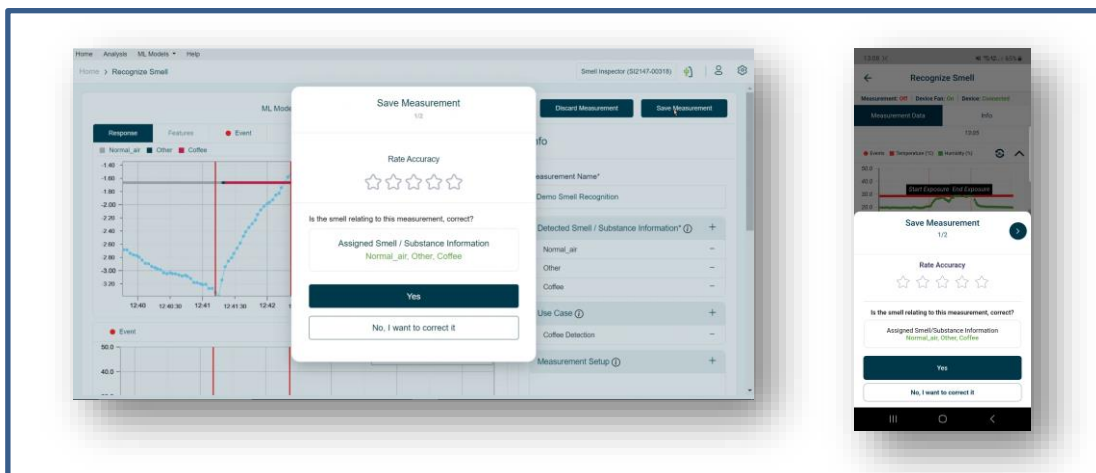


Figure 29. Correct Smell Information in case of Incorrect Prediction

You may give your feedback for an improvement of the ML model by rating the recognition accuracy.

If the measurement has Incorrect Smell assigned to it, you can correct it by selecting the 'No, I want to correct it' option from the popup. This will take you to the Smell / Substance Information list, where you can remove the incorrect smell. Deselect the incorrect Smell/Substance, as shown in Figure 30 (i.e., the incorrect smell is 'other' because we only measured 'coffee' scent to recognize it).

Incorrect Smell:

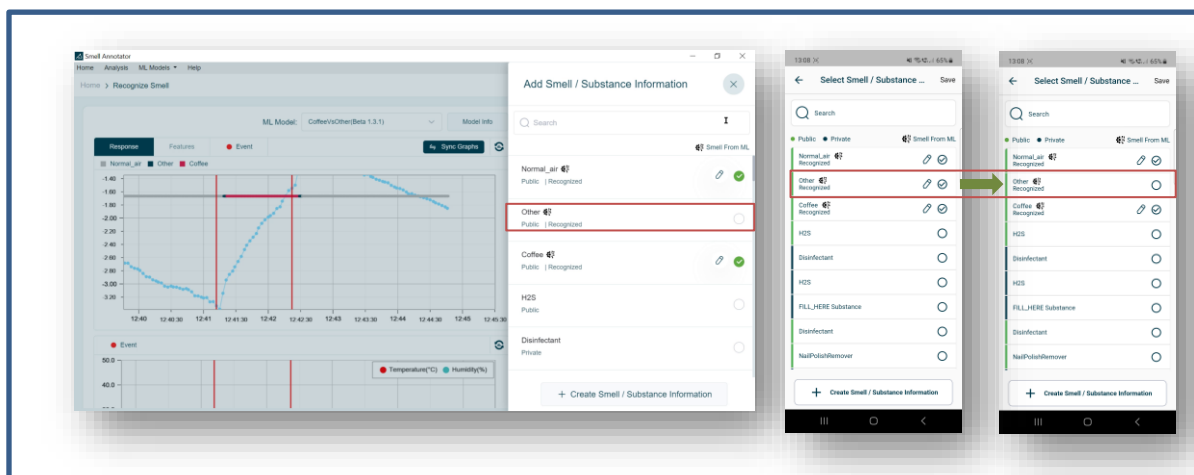


Figure 30. Removing associated Incorrect Smell from the list

Corrected Smell:

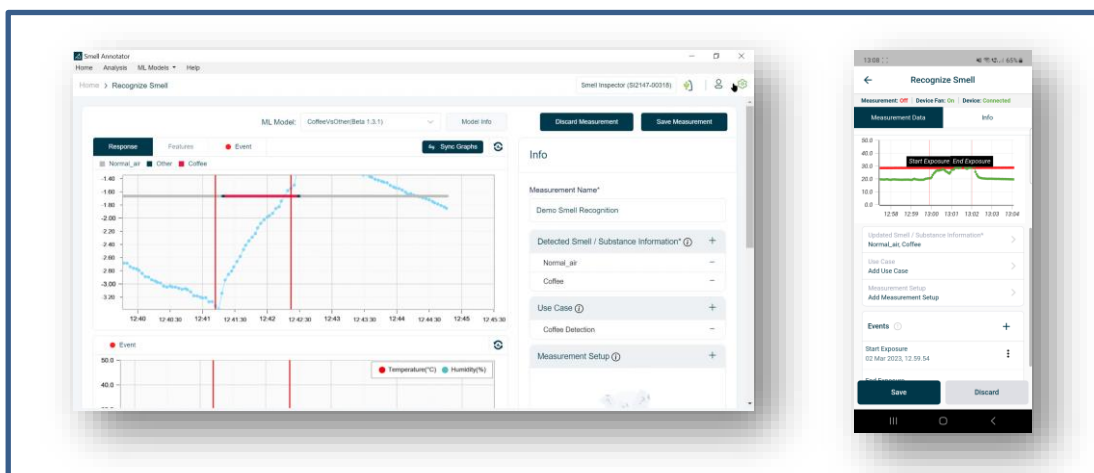


Figure 31. Corrected Smell/Substance Information

To save the measurement, click on 'Save Measurement' and then select the 'Yes' option in the reappearing popup since you have already corrected the Smell Information. Additionally, provide feedback by rating the accuracy of the model.

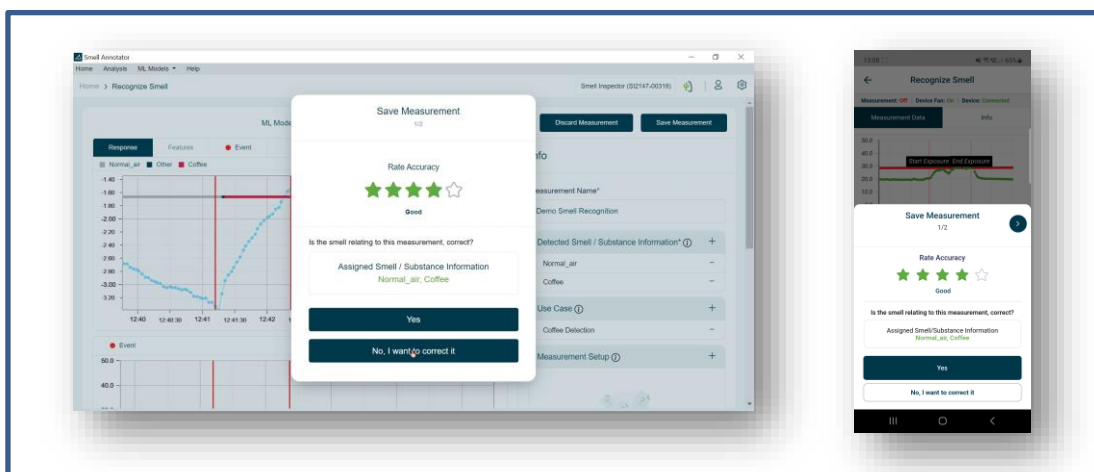


Figure 32. Add feedback with rating and check for Smell/Substance Information

As seen in Figure 33, a new popup will appear where you can set the "Measurement Name" and add a comment (optional). Click 'Save' to save measurement.

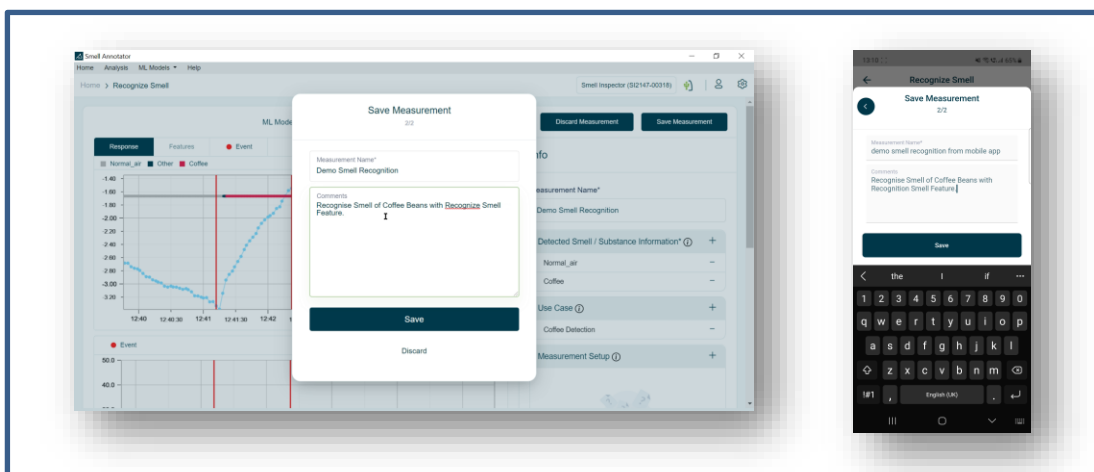


Figure 33. Add Measurement Name and comment to Save Measurement

3.4.11 Step 11: Measurement saved Successfully!

When a measurement is saved, the Measurement listing screen appears, with a successful message at the top as shown in Figure 34.

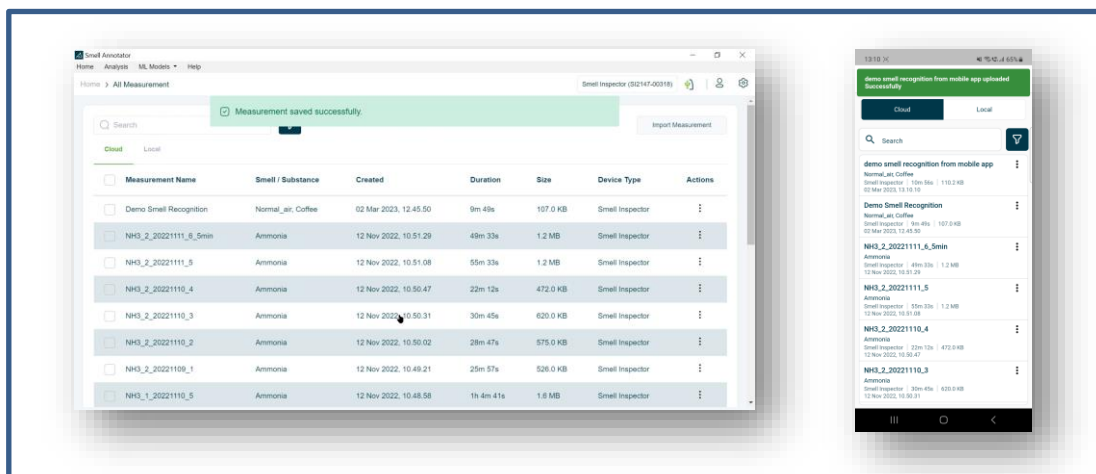


Figure 34. Measurement Saved

3.5 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.

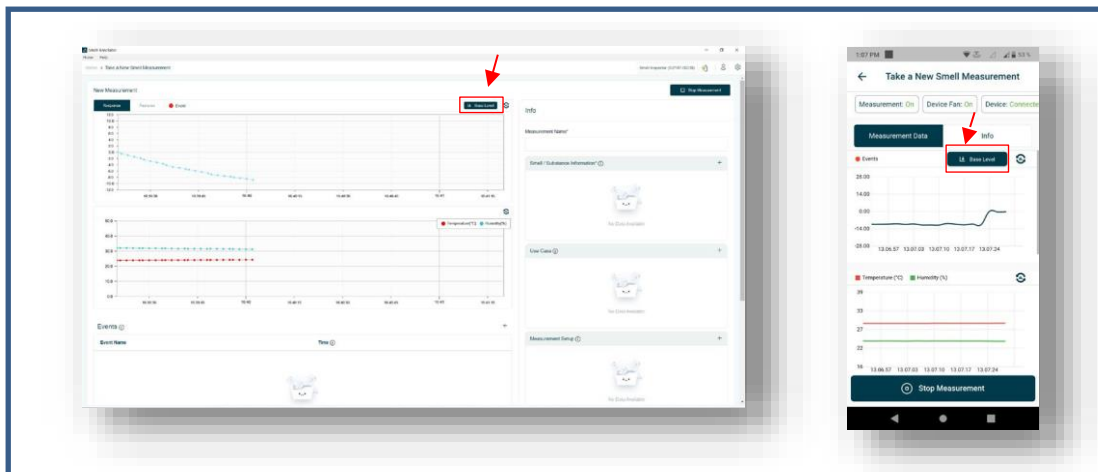


Figure 35. Reset Base Level of ongoing Measurement.

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.

3.6 Export 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.

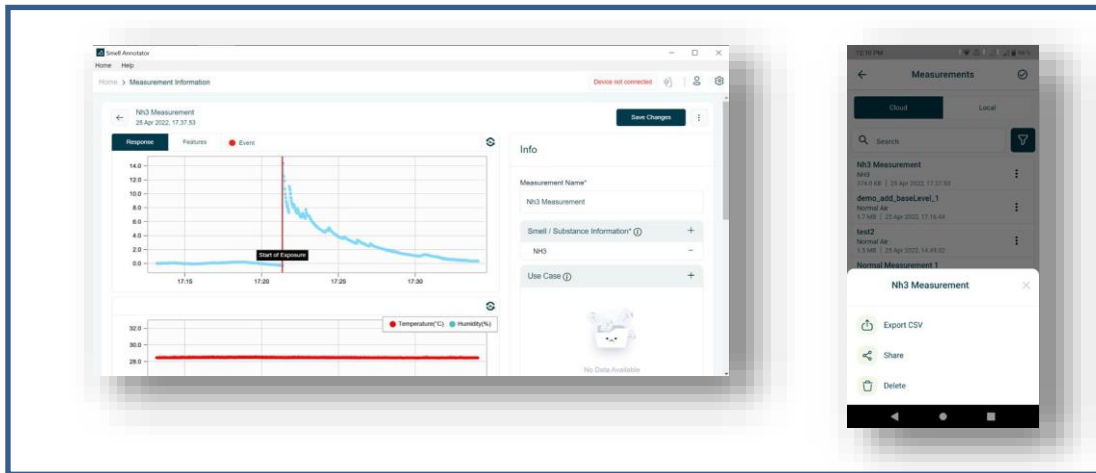


Figure 36. Export a Measurement as CSV File

3.7 View the Feature Graph

The featured graph represents the feature values of the Smell measurement. It gives the inside of the measurement. Currently, Feature graph is only available in desktop app.



Figure 37. Feature Graph

3.8 Measurement Analysis

Measurement Analysis provides you with 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 note: 'Analysis' feature is only available in the desktop app.

Please follow the steps below to perform a measurement analysis.

3.8.1 Step 1: In Home Screen, Select "Analysis"

Navigate to the 'Home' screen. Select 'Analysis'. The measurement listing screen will be opened.

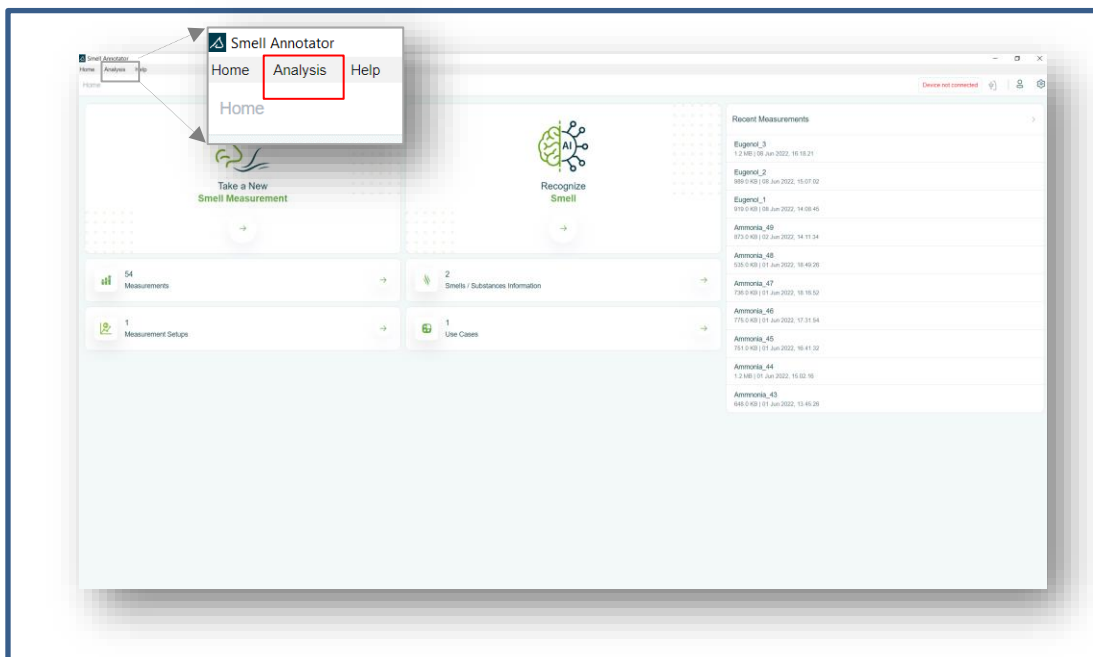


Figure 38. Navigation to Analysis

3.8.1 Step 1: Select Measurements to Analysis

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 34. You will only be able to select the measurements that fulfil the mentioned requirement.

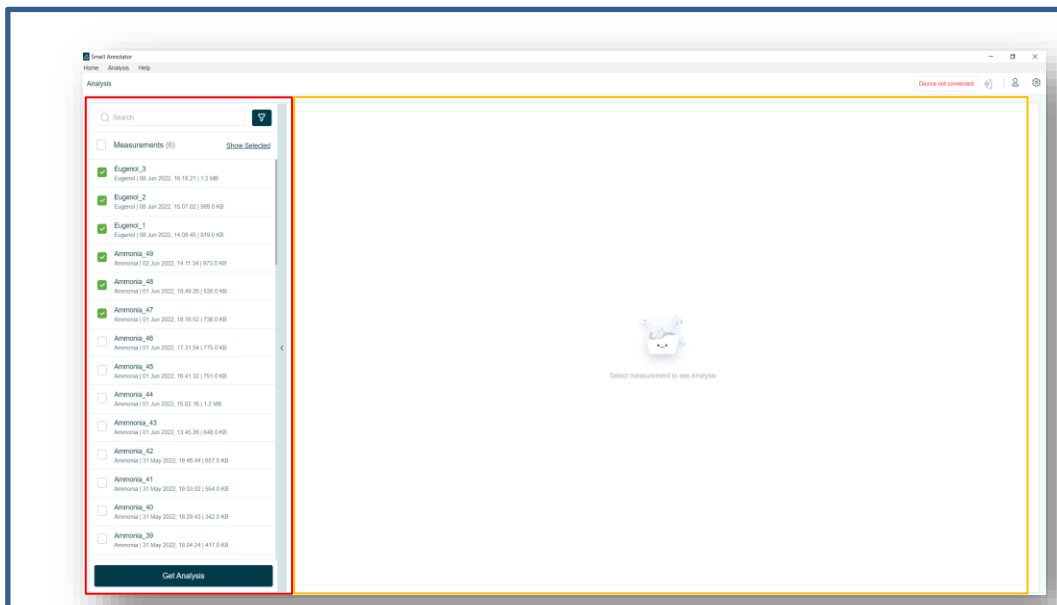


Figure 39. Analysis Screen – Measurement selection

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,

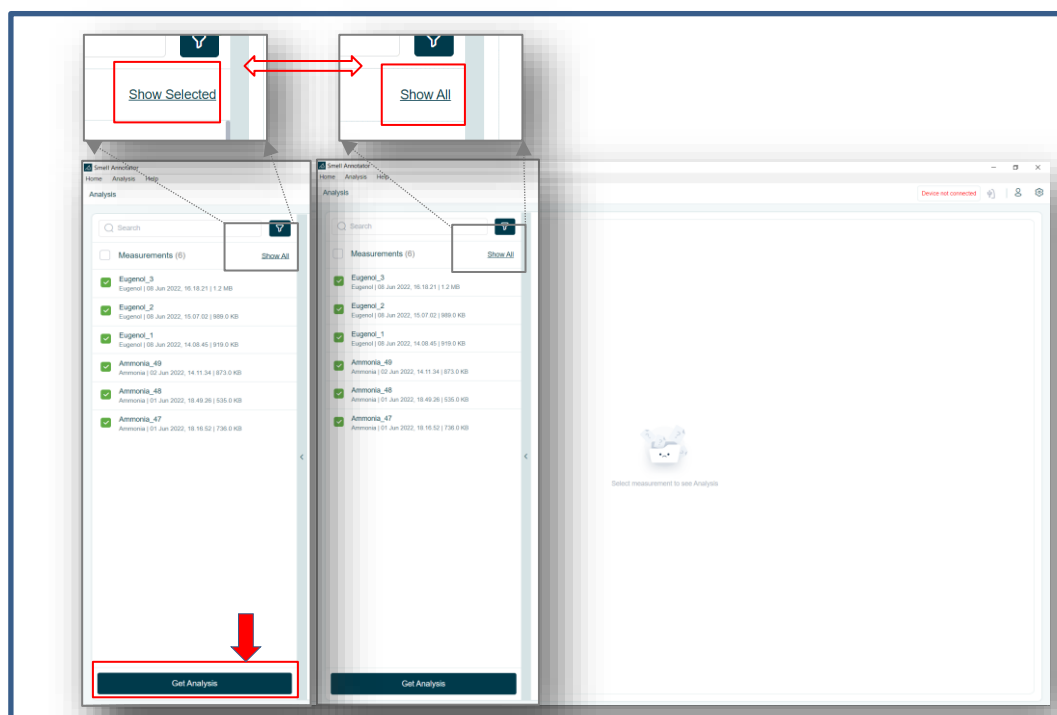


Figure 40. Analysis Screen –Get Analysis

3.8.3 Step 3: Click on 'Get Analysis'

Click the 'Get Analysis' button to get the Analysis of the selected measurements.

Now you should be able to see the screen below.

Please note that, LDA graph will only be generated, if in the measurement selection, at least two measurements with the same smell information are selected. Otherwise, the LDA graph cannot be provided.

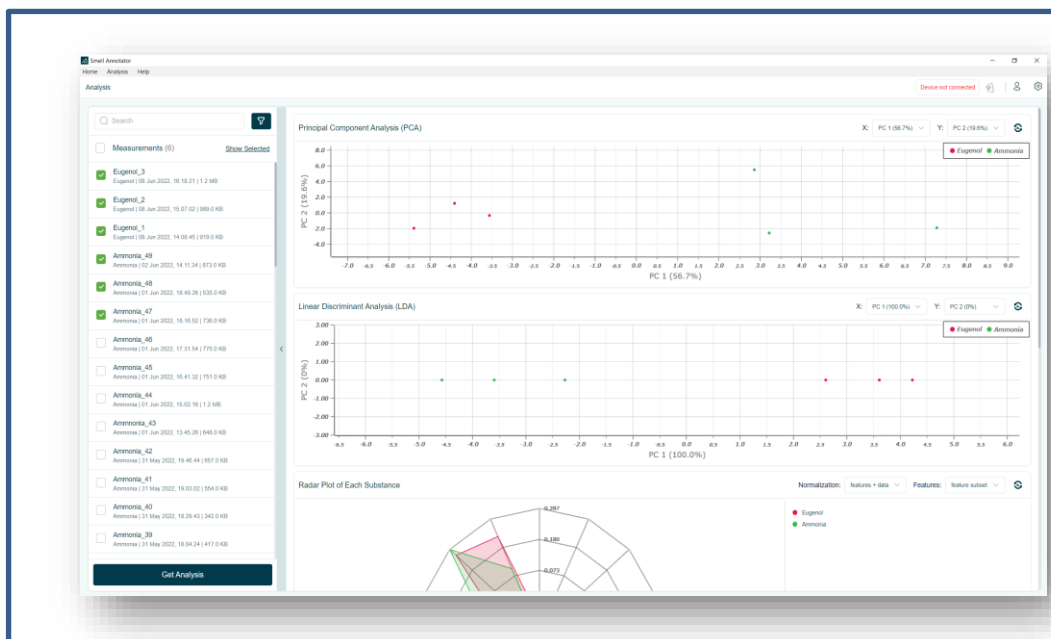


Figure 41. Analysis Screen – Analysis Graphs

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.

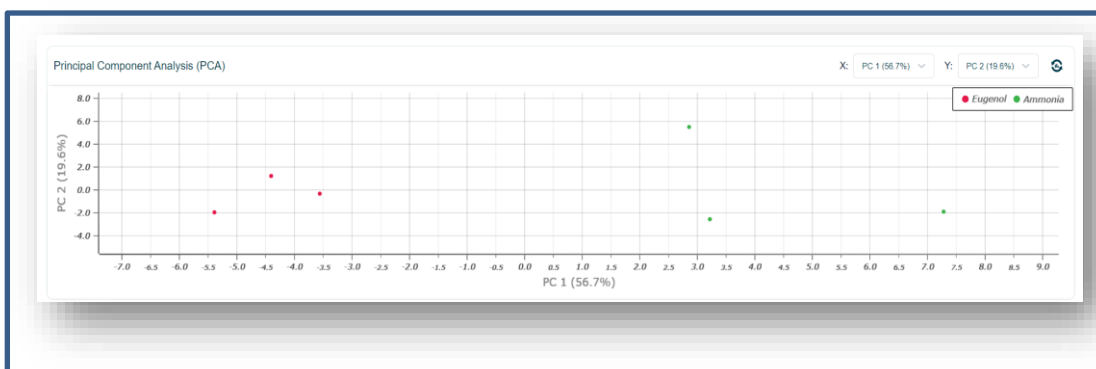


Figure 42. Analysis Screen – PCA

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 measurements of multiple smells 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%].

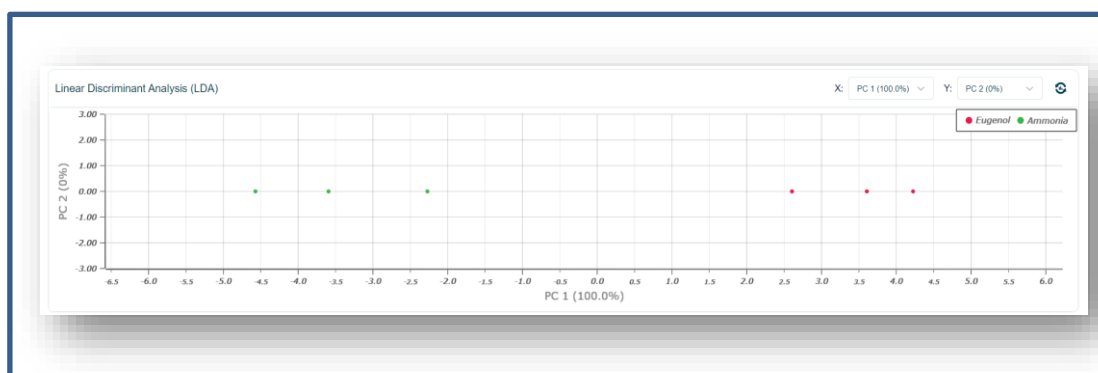


Figure 43. Analysis Screen – LDA

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.

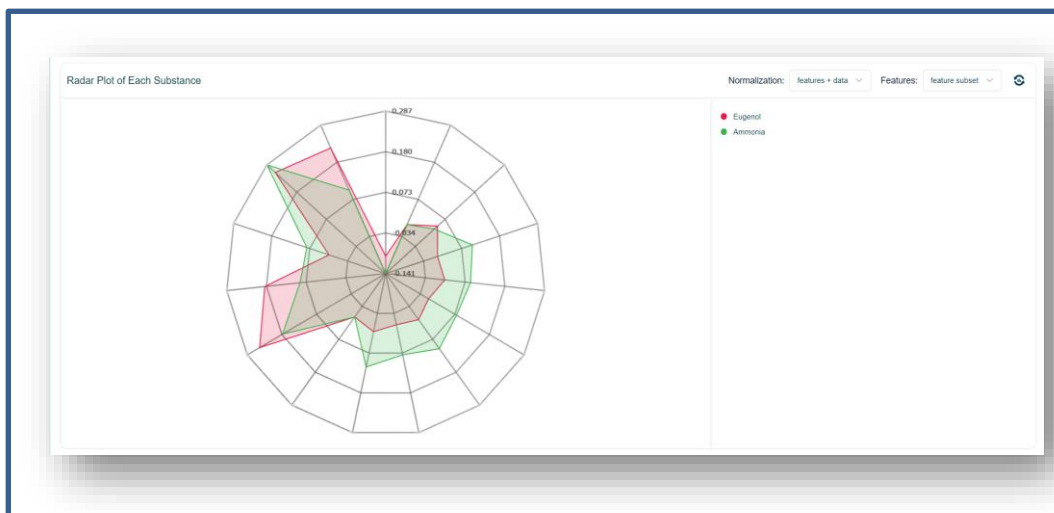


Figure 44. Analysis Screen – Radar Plot of Each Substance

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.

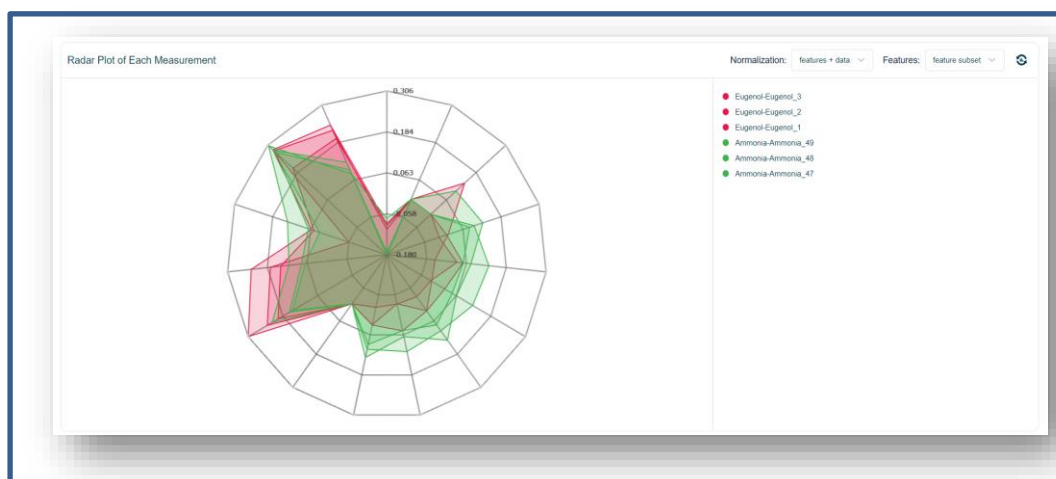


Figure 45. Analysis Screen – Radar Plot of Each Measurement

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.

3.9 Fan Control

Changing the fan speed of the Smell Inspector device will change the measurement airflow and may cause the measurement to behave differently.

3.9.1 Step 1: Go to Setting > Application > Fan Control

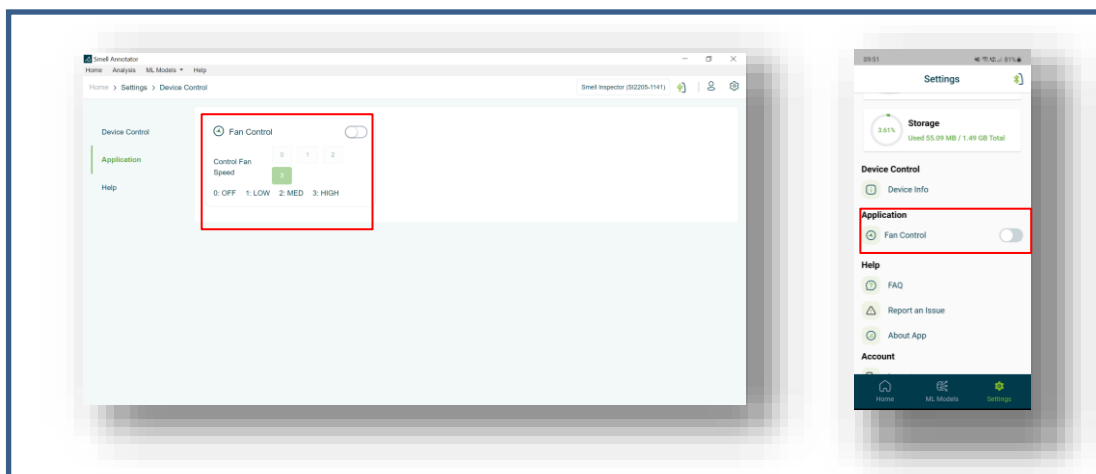


Figure 46. Fan Control - Step 1

3.9.2 Step 2: Turn On 'Fan Control'

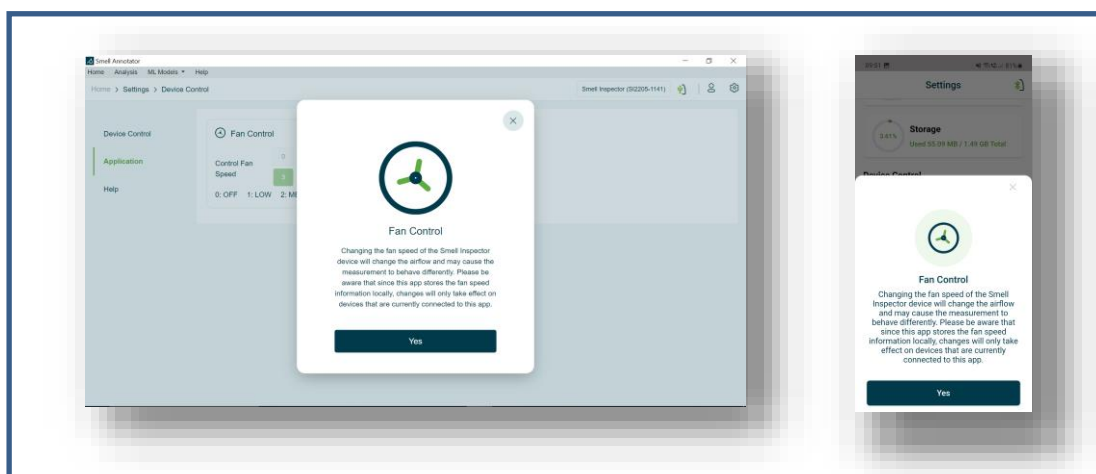


Figure 47. Fan Control - Step 2

In default setting, fan speed is set to 3.

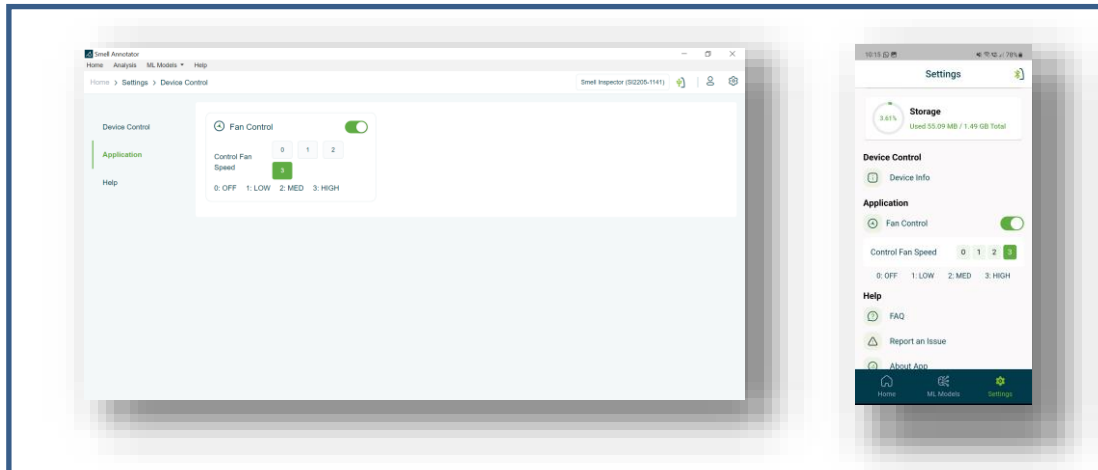


Figure 48. Fan Control - Step 3

3.9.3 Step 3: Change the fan speed (i.e., Setting Fan Speed to 0)

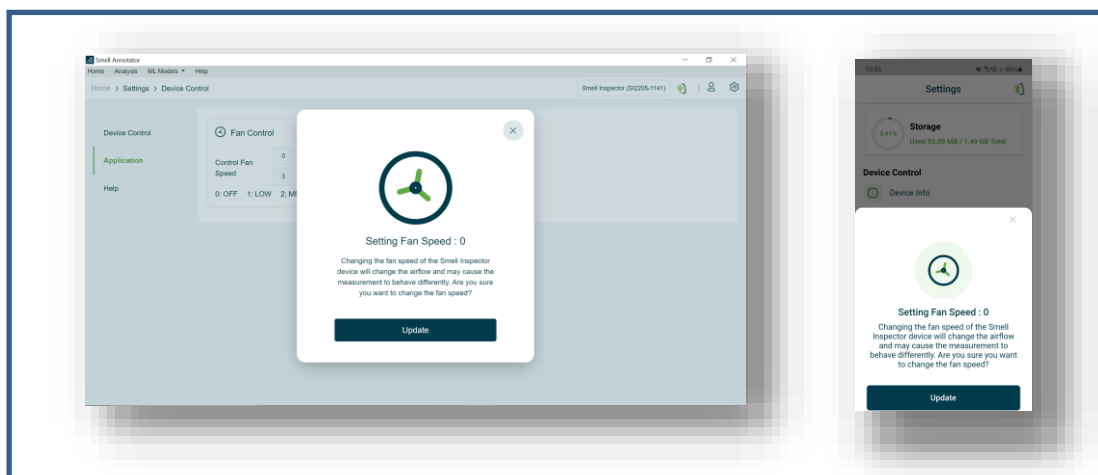


Figure 49. Fan Control – Step 4

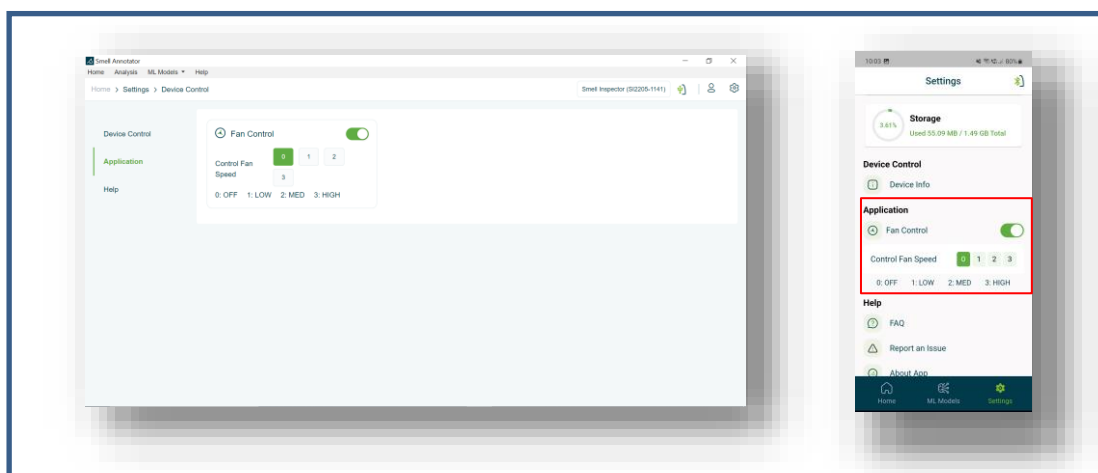


Figure 50. Fan Control - Step 5 (Fan speed set to 0)

4. FAQs

4.1 Account

4.1.1 How can I reset my password if I forget it?

If you forget your password, select the “Forgot your password?” or “Forgot Password?” option when signing in and enter your email address or phone number. You will receive an email or text message with instructions to reset your password.

4.2 Smell Annotator

4.2.1 Can I Use Smell Annotator without Signing in?

No, you need to sign in to use the Smell Annotator app.

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 Inspector

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> More information can be found in the Technical Manual.

4.3.2 How do I connect the Smell Inspector to the Smell Annotator?

The Smell Inspector device can be connected via Bluetooth to a mobile device and via USB cable to a Windows PC or laptop.

4.3.3 The Bluetooth connection is working, but only when the device is connected through USB. Why is this happening?

If you want to use the Smell Inspector device without a USB connection, you need to insert 2 AAA batteries into the device. After inserting the batteries, you may need to turn on the device by pressing and holding the power button for more than 4 seconds or by pressing the reset button.

4.3.4 What should I do if the Smell Inspector device cannot be turned on?

To turn on the device, press and hold the power button for at least 4 seconds. If you have inserted batteries, connecting the device to a USB cable will not automatically turn it on. You need to turn on the device by pressing and holding the power button.

4.3.5 Can I use the Smell Inspector with Smell Annotator without a USB connection?

Yes. You can use the Smell Inspector device by connecting to the mobile application via Bluetooth. Please remember to first insert batteries inside the device. Please note that, for the desktop Windows app, a USB connection to Smell Inspector is necessary.

4.3.6 Where can I update the Smell Inspector firmware?

You can update the Smell Inspector firmware using the Smell Annotator. On mobile app, firmware update is not possible.

4.3.7 Do the 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 significantly.

4.3.8 How should the Smell Inspector 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 exposure, the device should not move. Variations in airflow can lead to inaccurate measurements if precautions are not taken.

4.4 Measurement

4.4.1 How to take 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 Inspector device to the Smell annotator app.

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 inspector device 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 breathe directly into the smell/substance sample during exposure.

4.4.2 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.

4.4.3 Is it possible to see all the channels in visualization?

Yes. You can view 15 feature channels in saved measurements using feature graph.

4.4.4 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.

4.4.5 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.

4.4.6 Can I measure multiple smell measurements one by one without having a delay?

It is best practice to avoid measuring the different smells one after the other. A single smell should be measured in a single measurement. 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.

4.4.7 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.

4.4.8 About measurement drifts in the measurement, Is it normal?

Only drift as a response. This is possible due to the shorter distance of the smell inspector device to the substance or smell. Place the smell inspector 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 duration, which occur when the device is not exposed to the smell substance for a sufficient amount of time to obtain an accurate response. It is advisable to expose the smell substance to the smell inspector for at least 5 minutes.

4.4.9 What do I expect as a response in the measurement graph from the smell measurement?

Many factors influence the measurement response, including the type of smell substance, the measurement environment, and the concentration of the smell substance. We observed a sensor response ranging from a negative response of -50 percent to a positive response of 11,000 percent in the measure values when exposed to various smell substances under different conditions.

4.4.10 What if the measurement environment 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.

4.4.11 Can other Smells or changing smell environment can affect the actual measurement?

In most cases, it's recommended to conduct measurements in a smell-free environment because the presence of foreign smells in the measurement environment can have an adverse effect on the sensor's response. Therefore, when measuring, it's important to consider the potential impact of other smells or changes in the smell environment on the accuracy of the measurement, especially when taking measurement while wearing perfume/cologne on the

body.

4.4.12 Is it possible for two measurements of the same smell substance to have varied graph responses?

Yes, it is possible for two measurements of the same smell substance to have varied graph responses, especially if the measurements are taken in different environments. The environment can have an impact on the way the substance is sensed, leading to different responses in the measurements. Therefore, it is essential to conduct all measurements of the same smell substance in the same environment to ensure accurate and consistent results.

4.4.13 How can I export my measurements data?

You can export your measurements data in CSV format from the “Measurements” tab of the Smell Annotator app. Select the measurements you want to export, and then choose “Export” from the dropdown menu.

4.4.12 How can I delete a measurement?

To delete a measurement, select it from the “Measurements” tab and choose “Delete” from the dropdown menu. Note that this action cannot be undone.

4.5 Recognize Smell

4.5.1 What is the Smell Recognition feature, and how does it work?

The Smell Recognition feature is a technology that utilizes machine learning models to recognize and classify different smells or substances. It works by training the model with a large training dataset of smell samples, which allows it to identify specific patterns and characteristics of each smell. When a new smell is presented to the system, the model compares its features with those in its database and produces a prediction or probability score for each potential match. The more data the model is trained on, the more accurate and reliable its predictions will be.

4.5.2 Which smells can I recognize with Smell Inspector/Smell Board device?

The Smell Inspector device utilizes a specific ML model that has been trained to recognize and predict a specific set of smells. It is important to note that the model can only identify and classify smells that it has been specifically trained on.

As of 08.05.2023, the available model for the Smell Inspector device is designed for Coffee Recognition. Similarly, the Smell Board device has a model available as of 08.05.2023 for the recognition of Ammonia (NH₃) and Hydrogen Sulphide (H₂S).

We are continuously working on expanding the range of supported smells and substances in our Smell Recognition feature. Our team is actively developing new models to accommodate a wider variety of smells and substances. For the most up-to-date information on supported smells and substances, please refer to the respective Manual provided with the device.

We strive to enhance the capabilities of our Smell Recognition technology to meet the evolving needs of our users, and we appreciate your patience and understanding as we work to incorporate more models for different smells and substances.

4.5.3 How accurate is the Smell Recognition feature, and what factors can affect its performance?

The accuracy of the Smell Recognition feature can vary depending on several factors, such as the quality and quantity of the smell measurement data used to train the machine learning model, and the environmental conditions in which the smell/substance is recognized. In

general, the feature may perform better for some types of smells and environment than for others. It is also recommended to working in a controlled and stable environment to ensure the most accurate results while taking measurements.

4.5.4 How can I get a ML model for a specific use case?

If you have a specific use case in mind and require a ML model to address it, you may contact SmartNanotubes Technological GmbH with a detailed description of your requirements. Based on this information the company may create a model that is tailored to your use case. However, please keep in mind that it is currently not possible for us to create an individual model for each request. Instead, we will develop further models based on selected use cases and work with you to adapt them to your needs.

4.5.5 How can I ensure the accuracy of a ML model for smell recognition?

The accuracy of an ML model for smell recognition depends on several factors, such as the quality and quantity of the smell measurement data used to train the model, the diversity and representativeness of the smell sources, and the specific algorithms and parameters used in the model. To ensure the best accuracy, it may be helpful to test the model in a controlled and stable environment and compare its results to human experts or other benchmarking methods. The accuracy of a ML model can be improved by providing us feedbacks on the model performance and corresponding corrections of smell recognition when saving your smell recognition measurements. These measurements will be used to update (improve) corresponding ML model.

4.5.6 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.

4.5.7 Which smells can I recognize with Smell Inspector?

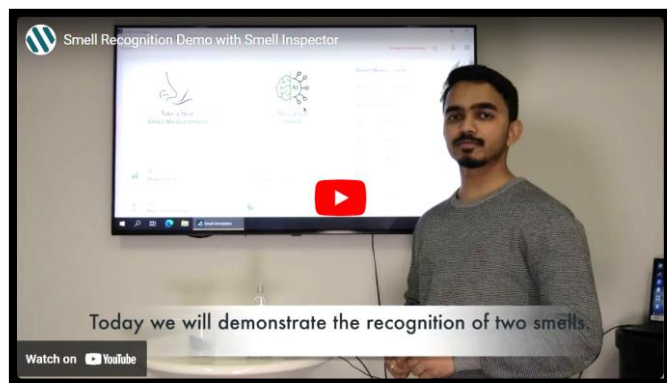
The Smell Inspector uses a specific ML model that can only recognize the smells listed in the model information. It's important to note that the model can only predict and identify smells it has been trained to recognize. To see a list of smells/substances that the model can correctly identify, refer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

4.5.8 Is there a video tutorial available for using the Smell Inspector device to recognize smells?

Yes, there are multiple video guides available for recognizing smells with the Smell Inspector device.

(1) Smell Recognition Demo with Smell Inspector:

You can access the video directly through this link: https://youtu.be/vpiNmES_G0s.



Smell Recognition Demo with Smell Inspector
https://youtu.be/vpiNmES_G0s

(2) Smell Recognition Demo with Smell Inspector:

You can access the video directly through this link: <https://youtu.be/g9WBvZgEAdU>.



This is a descriptive video how to use the Recognize Smell feature in Smell Annotator (<https://youtu.be/g9WBvZgEAdU>)

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 in the 1050–1150 range.

4.7 Technical Issues

4.7.1 Why is the app crashing on my device?

The app may crash due to a variety of reasons, including insufficient memory, outdated operating system, or software bugs. Try closing any other running apps and make sure your device is running the latest operating system and app version. If the problem persists, contact our support team.

4.7.2 Why is my device not detecting the Smell Inspector via Bluetooth connection?

Make sure that the device is powered on and within range of the Smell Inspector. Also, check that the Bluetooth connection is enabled on your device and that the Smell Inspector is paired with your device. If the problem persists, try resetting the Smell Inspector or restarting your device.

4.7.3 Why am I getting inaccurate measurements?

Inaccurate measurements can be caused by a variety of factors, including environmental conditions, improper use of the device, or hardware malfunction. Make sure to follow the measurement steps properly and take precautions to maintain a stable environment during measurements. If the problem persists, contact our support team for assistance.

4.7.4 Why am I unable to update the Smell Inspector firmware?

Make sure that your device is connected to the internet and that you have the latest version of the Smell Annotator app installed. Also, make sure that your Smell Inspector is connected to your device via USB cable. If the problem persists, try restarting your device or contact our support team for assistance.

4.8 Other

4.8.1 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/termservice/>

4.8.2 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

4.8.3 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.

4.8.4 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 Inspector without the Smell Annotator

As a Smell Inspector user, it is not mandatory to use Smell Annotator software for exploring smell-related applications. You are free to create and use your own software and methods to receive and process the data from Smell Inspector. You may use two options to connect the Smell Inspector to your application.

5.1 USB Measurements

The Smell Inspector device can be connected via USB cable to the USB port of the receiving device. You might need to install a USB driver from here (<https://www.silabs.com/developers/usb-to-uart-bridge-vcp-drivers>) . For more details, refer to page 4.

From the receiver side, it needs to set the correct USB port (COM xx) and Baud rate 115200 to get the data.

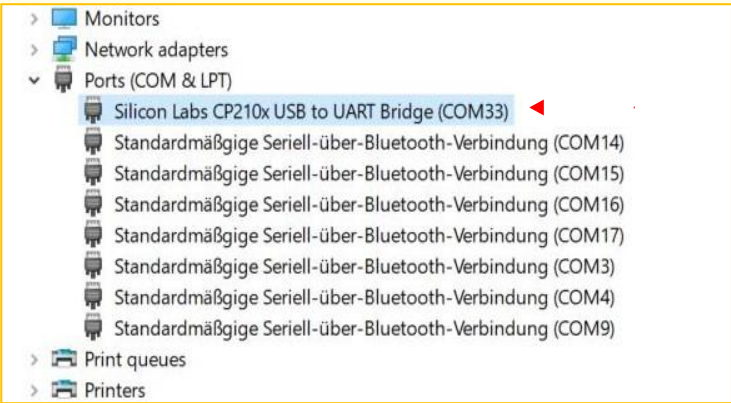
Technical Specification:

- Driver Installation - <https://www.silabs.com/developers/usb-to-uart-bridge-vcp-drivers>
- USB COM port - COMxx (xx is the port number)
- Baud rate - 115200
- Expected output - start;{64 resistance values}; temperature; humidity

Tips:

How to get COM port for smell inspector device?

Go to *Control Panel > Device Manager > Ports (COM & LPT)* > search for 'Silicon Labs CP210x USB to UART Bridge (COM xx)'. Here COM xx is your device's COM port.



The data values are in ASCII format. It begins with "start;" and then all the 64 resistance values are followed by temperature and humidity values (values positions 65 and 66). All these values are separated by a semi-colon (;). The total duration for one read-out is approximately 1.8 seconds.

While recording an event (when you press F1 for a short duration of time), "event" will be written on the serial monitor.

```

16:27:19.476 -> start-4406.1:4065.6:2409.7:1666.9:1244.6:1702.7:1853.3:1814.5:2768.8:1901239.9:2010608.5:2044918.0:2026218.9:8339.4:10008.1:15494.0:1997272.8:2007858.4:2003741.4:4648.1:1959985.2:1595
16:27:21.203 -> start-4407.1:4071.9:2419.5:1666.9:1244.2:1701.3:1852.9:1813.3:2767.9:1960594.6:1996593.5:1980766.1:2046127.9:2017170.1:8338.4:10015.5:15492.0:2019945.0:2026303.1:2064603.1:6464.6:1961434.6:1902
16:27:22.936 -> start-4407.5:4070.0:2418.9:1666.9:1244.2:1701.3:1853.9:1813.5:2767.6:1880038.9:1985454.0:2077842.6:1995236.6:2008545.1:8342.6:10009.0:15501.0:1961434.6:2011297.1:2064328.0:6461.6:1962103.4:2046
16:27:24.697 -> start-4409.9:4070.8:2418.6:1666.4:1243.9:1701.8:1853.4:1813.6:2765.2:1954935.2:2019945.0:1999993.9:2050273.4:2014747.8:8343.4:10018.7:15507.6:2010608.5:2015439.1:2002675.1:2064603.1:6464.6:1961434.6:1902
16:27:26.421 -> start-4409.8:4069.7:2417.6:1666.4:1244.0:1701.6:1853.1:1813.4:2763.8:1959940.1:2062978.0:1957653.2:2024123.5:1956348.8:8342.6:10013.2:15505.2:2011986.4:1999927.6:2029720.9:6469.9:2036440.0:1995
16:27:28.174 -> start-4409.6:4069.3:2417.5:1666.9:1244.0:1701.5:1853.0:1813.4:2765.0:1903661.9:2001357.1:2022729.0:2036400.9:1999953.6:8345.8:10020.7:15504.0:2018357.0:2033587.0:2078578.1:6469.2:1961249.4:1989
16:27:29.919 -> start-4405.1:4070.1:2418.2:1666.3:1244.1:1702.3:1852.8:1813.7:2764.4:1929351.0:2053140.9:2020421.4:1999993.9:2005515.9:8344.9:10013.5:15516.1:2017863.2:2004703.4:1999502.2:6473.8:1962772.8:2046
16:27:31.454 -> start-4404.0:4068.5:2417.3:1666.4:1244.0:1701.5:1853.5:1813.9:2764.2:1942434.8:1935392.2:2033587.0:1996593.5:2006045.0:8345.0:10013.8:15512.3:2008545.1:1978097.0:2007235.8:6470.3:1959940.1:1994
16:27:33.429 -> start-4403.9:4069.7:2417.6:1666.4:1243.9:1701.4:1852.7:1813.6:2767.0:1971786.8:2026218.9:1990502.2:2067963.8:1961904.8:8343.0:10017.1:15501.2:1949205.2:2045622.1:2009920.6:2009920.6:2009920.6:2009920.6:2009920.6
16:27:35.149 -> start-4404.2:4069.7:2417.6:1666.5:1243.8:1701.4:1853.0:1813.3:2765.6:1918634.1:1965187.8:1986126.0:1999912.8:2031125.0:8344.0:10018.5:15501.0:1943117.2:2059622.1:2056166.5:6468.1:1959514.6:2093
16:27:36.995 -> start-4404.0:4071.1:2418.1:1666.5:1243.8:1701.6:1852.8:1813.4:2765.0:1965845.8:2020318.4:2004431.4:2020318.6:2005781.2:8339.2:10010.9:15497.5:2020318.6:1917068.1:2053140.9:6470.7:1940509.0:2007
16:27:38.432 -> start-4402.2:4070.1:2418.1:1665.0:1243.7:1701.4:1852.6:1813.3:2762.2:1931532.4:2003420.9:1902560.4:2006406.2:2055115.9:8343.8:10014.1:15496.3:1991352.6:2026892.4:2093907.2:6469.2:2001357.1:2002
16:27:40.411 -> start-4402.4:4069.4:2416.5:1665.0:1244.0:1701.5:1852.0:1813.6:2764.4:1911451.0:2018570.0:1970463.4:2019945.8:2030828.9:8342.0:10022.0:15508.1:2045630.6:2078578.1:2029019.4:6469.9:1957653.2:2004
16:27:42.126 -> start-4401.7:4067.7:2416.7:1665.6:1244.0:1701.2:1852.6:1813.5:2760.9:1905050.0:2026218.9:1978763.8:2010608.5:2020318.6:8347.6:10021.3:15513.3:2030422.6:2002380.9:2013664.0:6469.9:2007856.4:1990
16:27:43.896 -> start-4402.0:4069.7:2417.6:1665.6:1243.9:1701.9:1853.0:1813.6:2764.4:1929351.0:1994559.0:1999912.8:2019945.8:2009920.6:1978763.8:2010608.5:2009920.6:8348.0:10022.3:15505.6:1995914.9:2020267.9:2020267.9:2020267.9:2020267.9:2020267.9
16:27:45.629 -> start-4402.0:4069.7:2416.6:1665.7:1244.0:1700.8:1852.0:1813.6:2764.1:1953745.0:2017170.1:2003747.4:1989827.6:1959940.1:8348.0:10034.0:15506.3:2019251.0:2020267.9:2020267.9:2020267.9:2020267.9:2020267.9
16:27:47.372 -> start-4400.8:4067.7:2416.7:1665.0:1243.7:1700.7:1852.9:1812.6:2762.6:1924953.8:2055296.6:1976765.2:2053140.9:2021336.4:8340.8:10022.1:15525.9:1988480.0:1995914.9:1992772.8:6469.9:1961249.4:2039
16:27:49.130 -> start-4401.6:4066.6:2416.3:1665.0:1243.7:1701.4:1852.5:1813.0:2763.5:1914567.9:1985454.0:2032179.4:2029720.9:2030422.6:8342.7:10021.2:15514.4:2041363.6:1911451.0:2048440.5:6467.3:1949205.2:2118
16:27:50.852 -> start-4400.5:4068.3:2416.7:1666.0:1243.5:1701.1:1852.7:1813.1:2762.0:1961249.4:2014747.8:1999993.9:2039236.9:2091907.2:8346.5:10024.0:15514.4:1985454.0:2020421.4:2003747.4:4648.1:1959514.6:2093
16:27:52.619 -> start-4401.9:4067.7:2417.3:1665.9:1244.0:1701.4:1852.3:1813.4:2762.7:1909345.6:1965187.8:1995914.9:2073806.5:2036408.0:8342.6:10020.8:15513.3:2020267.9:1966481.6:2048127.9:6470.3:1961904.8:2012
16:27:52.659 -> start-4401.9:4067.7:2417.3:1665.9:1244.0:1701.4:1852.3:1813.4:2762.7:1909345.6:1965187.8:1995914.9:2073806.5:2036408.0:8342.6:10020.8:15513.3:2020267.9:1966481.6:2048127.9:6470.3:1961904.8:2012
16:27:53.255 -> start-4400.7:4068.0:2416.6:1666.1:1243.8:1701.3:1852.9:1812.9:2763.7:1911451.0:2017170.1:2010608.5:2041363.6:1955046.0:8341.9:10020.6:15523.5:2036408.0:1974770.9:2002380.9:6467.2:2039236.9:2041
16:27:54.988 -> start-4400.8:4066.6:2416.4:1665.7:1243.9:1700.8:1851.9:1813.0:2763.9:1906466.9:1943077.5:2013366.0:2059622.1:1971786.8:8342.9:10012.2:15526.6:1959940.1:1964530.2:1951146.2:6466.3:1951796.8:2029
16:27:56.753 -> start-4409.6:4066.6:2416.4:1665.7:1243.9:1701.2:1852.4:1813.0:2762.9:1941150.5:2076066.1:1962560.4:2091162.2:1979430.8:8347.6:10014.1:15504.1:1931254.8:2005115.9:1963973.1:6469.9:1961249.4:2048

```

Figure 51. USB measurement format

While giving commands to operate the fan, i.e., "FAN1", "FAN2", "FAN3", "FAN0", the fan will initially operate at full speed for 1 second before going to its specified speed. If the fan is operating at speed 1 and we give the command "FAN2", the fan will go to its full speed for 1 second first and then operate at a speed corresponding to the "FAN2" command. This functionality is also implemented in Bluetooth operating mode.

All the commands provided to the Smell Inspector via USB have a newline ("`\n`") character at the end of the command.

Commands: "FAN1", "FAN2", "FAN3", "FAN0", "GET_INFO".

5.2 Bluetooth Measurements

The data transmitting in the Bluetooth measurements mode is different than in the USB measurements mode. In Bluetooth measurements mode we there are different "characteristics" to represent different measurements like resistance values, temperature, humidity, and operating the fan. These characteristics are represented with the help of a unique ID known as the UUID.

- **Service UUID-** 4f4fc201-1fb5-459e-8fcc-c5c9c331914b
- **Resistance Characteristic UUID-** beb5483e-36e1-4688-b7f5-ea07361b26a8 (Read only)
- **Temperature Characteristic UUID-** 688091db-1736-4179-b7ce-e42a724a6a68 (Read only)
- **Humidity Characteristic UUID-** 0515e27d-dd91-4f96-9452-5f43649c1819 (Read only)
- **Event F1 Characteristic UUID-** 34231e68-f44f-11eb-9a03-0242ac130003 (Read, Write)
- **Fan Characteristic UUID-** 6e60febb-dbdd-458b-8eec-68424699261c (Read, Write)
- **Firmware Information Characteristic UUID-** 34737892-2f2e-4ee5-9a0f-e0034cf643bc (Read,Write)

For resistance values in Bluetooth measurements mode, one gets the resistance value of one channel at a time. This continues for all 64 channels first. After all the resistance values are measured, one gets the temperature, and after receiving the temperature, one gets the humidity value. All these 66 values (64 resistances, temperature, and humidity) take approximately 1.8 seconds. All received values are in ASCII format.

After pressing F1, one sees the "event" being passed on to "Event F1 Characteristic UUID". A flag named "annFlag" (same as the one used in USB measurement) is set to true whenever F1 is pressed. Passing commands "FAN1", "FAN2", "FAN3", "FAN0" to the "Fan Characteristic UUID" by clicking on "W" controls the fan speed 1, 2, or 0, respectively. Passing the command "GET INFO" to the "Firmware Information Characteristic UUID" by clicking on "W" gives the firmware information.

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 Inspector without the Smell Annotator app, you must consider these factors.

SmartNanotubes Technologies GmbH
Dresdner Str. 172
01705 Freital
Germany
www.smart-nanotubes.com