# Experiments, and results

## Experiments

In this chapter, the E-nose module was tested. In fact, assuming that the database and the AR application work perfectly, the fundamental inputs of AROD are the smell analysis. First, the E-nose was used to collect and analyse the smell composition of four samples with completely different odours:

* Used engine oil
* Medical alcoholic solution “Corsodyl”
* Sun Lotion “Nivea”
* Perfume “Bleu de Chanel”

The dynamic headspace sampling technique was used to make the measurements. This technique is based on the projection of a continuous fresh air flow in the headspace of the sample while odorant air is analysed to increase the evaporation rate at the surface of the sample and consequently inject a more odorant particle-concentrated air in the E-nose. The principle is illustrated with the Figure 1 below:



Figure 1: Dynamic Headspace Sampling Technique

For each scent 10 measures were taken successively using the same process to estimate their odour identities. The calibrated resistances were calculated once at the beginning of the 10-measure series reuse during the whole series. The cleaning sequences were applied between each measurements. The sample was injected for 5 seconds into the E-nose and then only the fresh air flow was still active for the analysis duration.

The second experiment was to use the analysed odour identities to recognize the samples randomly analysed with the “blind test” principle to confirm and validate the smell recognition skill of AROD. Each sample was analysed twice in a random order.

## Results and discussion

The results of the first experiment have been plotted into the following graphs. There are three graphs per sample, one for each gas sensor:

Figure 2: R1/R01 results of 10 Medical Alcohol sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 3: R2/R02 results of 10 Medical Alcohol sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 4: R3/R03 results of 10 Medical Alcohol sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 5: R1/R01 results of 10 Used Engine Oil sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 6: R2/R02 results of 10 Used Engine Oil sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 7: R3/R03 results of 10 Used Engine Oil sample analysis, RL=10kΩ, T=27°C, 40%<RH <50%

Figure 8: R1/R01 results of 10 Sun Lotion sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 9: R2/R02 results of 10 Sun Lotion sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 10: R3/R03 results of 10 Sun Lotion sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 11: R1/R01 results of 10 Perfume sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 12: R2/R02 results of 10 Perfume sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

Figure 13: R1/R01 results of 10 Perfume sample analysis, RL=10kΩ, T=27°C, 40%<RH<50%

For every cases, several similarities have been noticed. All the curves follow the same pattern. Close to the calibration value at the beginning, the ratios jump down to a plateau after the injection of the odorant air. This pattern is analysed in details below.

Before and at the beginning of the smell injection, the resistance ratio is close to 1 for the first tests as there should be only fresh air in the sensors chamber and consequently values similar to calibration values. However, the ratios drop to lower values with the successive analysis, especially with “strong odour” like perfume and medical alcohol. This can let suppose that in some cases there are still odorant particles coming from the previous analysis in the sensors chamber although the cleaning stages are done. The sensors chamber volume is approximately 560cm3 whereas the pumps flow rate is 200mL/min or 200cm3/min so for the cleaning stage 1 which lasts 200 seconds, the total amount of fresh air injected into the sensors chamber is about 670cm3 which means that more than the total polluted volume of the sensors chamber is renewed. Hence the cleaning process should be reviewed in case of “strong odour” analysis.

The second part of the pattern is the drop of ratios start at the moment when the odorant air reach the sensors chamber, which represents in the configuration of the air circuit a mean time of 2,5 seconds or 5 measurement points. This transitional state can last between 3 and 10 seconds depending on the sample under analysis.

Finally after the drop, a plateau or constant value is reached. The ratio obtained corresponds to the moment when the injected odorant air is fully present into the chamber and stay at the same concentration of odorant particles. The partial odour identity composed of the results of the three sensors is consequently identified. As the plateau remains constant until the end of the analysis in every cases, the duration of the analysis could be reduced from a minute to 20 seconds which at least allows 5 seconds of plateau section. This will fasten the maintainer’s future analysis.

Although having different sensitivities, sensor 1 and 3(respectively TGS2620 and TGS2600), have very similar behaviours when used with the four samples of the study. Sensor 2 (TGS2603), sensitive to very low concentration odorous gases presents lower ratios.

In most of the case, the 10 analysis presents good repeatability of the final plateau converging to same ratios area although the initial values before the drop are dispersed .The table below presents the mean and dispersion of each graph:

Table 1: Means and dispersions values of the plateau phase of the samples analysis

|  |  |  |
| --- | --- | --- |
|   | **Medical Alcohol** | **Used Engine Oil** |
| S1 | S2 | S3 | S1 | S2 | S3 |
| **Mean** $\overbar{X}$ | 0,33 | 0,29 | 0,32 | 0,86 | 0,57 | 0,86 |
| **Dispersion σ** | 0,02221111 | 0,01286684 | 0,02043961 | 0,0421637 | 0,23659858 | 0,03994441 |
|   | **Sun Lotion** | **Perfume** |
| S1 | S2 | S3 | S1 | S2 | S3 |
| **Mean** $\overbar{X}$ | 0,89 | 0,37 | 0,9 | 0,24 | 0,08 | 0,22 |
| **Dispersion σ** | 0,14353087 | 0,11419282 | 0,13938356 | 0,04672615 | 0,01100505 | 0,04483302 |

As the Table 1 shows, the sensors values of strong odours, perfume and medical alcohol, proposed very little dispersion, assessing a correct odour identity identification. However, sensor 2 presents large dispersion for the used engine oil sample and the three sensors show also high dispersion on the sun lotion sample analysis. As a consequence the odour identities of both oil and sun lotion will have to be taken with caution due to the low precision of the analysis. This could be explained by the fact the used oil and the sun lotion are made with several important compounds compared to the two strong odours. Moreover, their volatilities are less important than with perfume and alcohol, composed of VOC. Thus the sensors conductivity do not manage to take precisely the same value after each test. The solution could then be to add numerous other sensors with different compounds selectivities and excluded the inaccurate sensors results to create the odour identity. All the same, the odour identities highlighted by the previous tests are displayed on the following graph:

Figure 14: Odour Identities of the 4 samples with fresh air as reference

The dispersion values σ are used as lower and upper bounds and implemented in the comparison process between the analysis values and odour identities values as following:

Correct identification if:

$$\overbar{X}x-σx\leq \frac{Rx}{R0x}\leq \overbar{X}x+σx$$

Potential identification if:

$$\overbar{X}x-2σx\leq \frac{Rx}{R0x}\leq \overbar{X}x+2σx$$

Incorrect identification if:

$$\overbar{X}x-2σx\geq \frac{Rx}{R0x} or \frac{Rx}{R0x}\geq \overbar{X}x+2σx$$

In these identification bounding equations,

$\overbar{X}x$is the mean of ratios given in table 5-1, x=(1, 2 or 3).
$σx$ is the dispersion of the values given in table 5-1, x=(1, 2 or 3).
$\frac{Rx}{R0x}$is the value of sensor x (1, 2 or 3) of the resistance ratio of the odorant air under analysis.

The second experiment consisting in blind testing the samples has been done. The random order of analysis is the following:

1. Used engine oil
2. Medical alcohol
3. Perfume
4. Used engine oil
5. Sun lotion
6. Perfume
7. Sun lotion
8. Medical alcohol

Using the aforementioned identification technique the results are presented into the following table. A colour code is used based on the previous equations; green for correct identification, orange for potential identification and red for incorrect identification.

Table 2: Resistance ratios of the second experiment with colour code based on identification bounding equations