**10 Primary Odor Classes**

The e-nose classifier used the ten odor classes described as follows. These basic categories of odors were proposed by the researchers at the University of Pittsburgh and Bates College [1].

1. Fragrant

The fragrant smells are treated alike with perfumery, floral, cologne, and rosy smells. These are the ones that seem light and natural, what is typically described by perfume and cologne manufacturers as grassy or herbal.

i.e., Perfume, rose, cologne

2. Woody

This category refers to the deep, earthy smells that remind human of the outdoors. The smells are distinct in nature, which makes them easily recognizable. Musty, moldy, heavy, burnt, and smoky scents are included in the woody odor.

i.e., Mold, wood, grass

3. Fruity

Contrary to the hearty musk of the outdoors is the light, fresh scents associated with cherries, peach, strawberries, banana, and certain perfumes that draw upon natural aromas are classified as fruity odor. Unlike the sharp and bitter freshness of lemon, non-citrus fruit smells feel more smooth or silky to the nose.

i.e., Pineapple, cherry, banana

4. Chemical

The human nose is particularly very sensitive at detecting synthetic smells. These smells include ammonia, bleach, gasoline, paint, and felt tip markers odors. Alcohol and disinfectants are also under this category.

i.e., Gasoline, solvent, paint

5. Minty/Peppermint

The minty/peppermint smell is described as cool, refreshing, and exhilarating odor. It became synonymous with cleanliness and is ubiquitous among oral hygiene products for this very reason. Spicy odor falls into this category.

i.e., Eucalyptus, peppermint, camphor

6. Sweet

Diverging from sweetness detected in fruits, the aromas of things such as chocolate, vanilla, almond, honey, cinnamon, and malty scents are classified as sweet odors. They are warm, and often light. It is frequently sold as creamy or rich.

i.e., Vanilla, chocolate, caramel

7. Popcorn

Popcorn is considered as an earthy smell that is not quite grass or wood. It was grouped with other distinct smells such as peanut butter, burnt, nutty, heavy, and warm.

i.e., Popcorn, peanut butter, almond

8. Lemon

The scent of lemon, orange, and citrus connote freshness with a hint of sweetness and sharpness that makes it unique from the others. It’s light and acidic, and the human nose knows it instantly.

i.e., Orange, lemon, citrus

9. Pungent

These smells include sour milk, fecal matter (e.g., manure), sweat, and the natural smell of things that have turned putrid or foul. These scents make human reel the instant it is detected. Oniony and garlicky smells also fall into this category.

i.e., Garlic, onion, burnt rubber

10. Decayed

Decayed smells are those that cause to dry heave the person when the nose detects them in heavy enough concentrations. This category is not merely unpleasant. They are considered as usually insufferable.

i.e., Sour milk, vinegar, fecal

Reference:

[1] Jason B. Castro, Arvind Ramanathan, Chakra S. Chennubhotla. Categorical Dimensions of Human Odor Descriptor Space Revealed by Non-Negative Matrix Factorization. PLoS ONE; 8 (9): e73289 DOI: 10.1371/journal.pone.0073289, 2013.

Here is the list of the actual samples taken. A series of measurements was captured for each one. Five signals for each sensor was obtained and sent to the server for processing. This was repeated 3 times per sample. Thus, a raw data matrix 15x10 for each sample was obtained for subsequent processing or pretreatment. The 10 samples per odor class and 15 readings per sample collectively yielded a 1500x10 (readings by feature/sensor) available dataset. You can find the consolidated measurements in the same link.

**Table I Samples per Odor Class**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Class | Samples | | | | |
| Fragrant | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22532153_10207578447137984_613647579_o.jpg  Cologne 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22532226_10207578447177985_1235307664_o.jpg  Softener1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22546952_10207578447017981_268180279_o.jpg  Detergent | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\liquid soap.jpg  Liquid Soap | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22496930_10207578448098008_363667930_o.jpg  Candle1 |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22497089_10207578447057982_1914636864_o.jpg  Cologne 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22496908_10207578446897978_997007753_o.jpg  Softener2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22522204_10207578446937979_1166483814_o.jpg  Deodorant | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22556137_10207578446817976_207342634_o.jpg  Shampoo | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fragrant\22497171_10207578446857977_97868189_o.jpg  Candle2 |
| Woody | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22522252_10207578448418016_86180848_o.jpg  Matches | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22553462_10207578448538019_878222959_o.jpg  Fresh grass | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22429488_10207578448338014_1863897294_o.jpg  Wood 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22522106_10207578448378015_1613192454_o.jpg  Wood 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22553559_10207578448618021_816174964_o.jpg  Leaves 1 |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22546740_10207578448498018_1054220782_o.jpg  Leaves 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22532390_10207578448178010_955510486_o.jpg  Card Board | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22546769_10207578448578020_881692232_o.jpg  Cigar Pack | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22553624_10207578448658022_331445308_o.jpg  Laurel | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Woody\22497066_10207578448218011_2033146498_o.jpg  Wet Paper |
| Fruity | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\Banana 2.jpg  Banana | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\Banana.jpg  Banana 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\Pear.jpg  Pear | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\Apple.jpg  Mango | Fruit Salad |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\grapes.jpg  Grapes | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\Raisin.jpg  Raisin | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22854639_10207641807361950_679478179_n.jpg?oh=83fefe6ffd9958feca382fe87fe4a517&oe=59F618D7  Honey | Avocado | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Fruity\Fruity\mango.jpg  Mango |
| Chemical | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Bleach.jpg  Bleach | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Butane.jpg  Methane | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Ethyl Alcohol.jpg  Alcohol | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Rugby.jpg  Rugby | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Disinfectant.jpg  Disinfectant |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Lubircating Oil.jpg  Lubricant | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\Gasoline.jpg  Gasoline | Diesel | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Chemical\Chemical\thinner.jpg  Thinner | Sulfuric |
| Minty | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Totthpaste 1.jpg  Toothpaste | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Tea Bag.jpg  tea | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Vic vapor Rub.jpg  Vapor rub | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Efficacent Oil.jpg  Oil | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\mouth wash 2.jpg  Freshener 1 |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Toothpaste 2.jpg  Toothpaste | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Peppermint\Peppermint\Aceite de Manzanilla.jpg  Acete | Eucalyptus | Peppermint | Sulfuric |
| Decay | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\spoiled milk.jpg  Milk | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\dog feces.jpg  Dog Feces | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\decayed chicken.jpg  Chicken | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\decayed vegetable.jpg  Veggies | Rotten fish |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\decayed pork.jpg  Rotten pork | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\decayed banana.jpg  Rotten fruit | Salted egg | Rotten egg | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\decaying\decayed apple.jpg  Rotten apple |
| Pungent | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\Onion 2.jpg  Onion | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22894688_10207641807481953_193104135_n.jpg?oh=81782b417e437a99fe46a33f071193c7&oe=59F62AFA  Blue Cheese | Cigar 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\white onion.jpg  Onion 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\Garlic.jpg  Garlic 1 |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\Onion.jpg  Onion | Burnt Rubber | Cigar 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\white onion 1.jpg  Onion 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Pungent\Pungent\Sauteed Garlic.jpg  Garlic 2 |
| Citrus | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\Orange.jpg  Orange | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\Lemon 2.jpg  Lemon 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\Lemon.jpg  Lemon 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\dalandan 1.jpg  Mandarin | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\dalandan 2.jpg  Dalandan |
| Juice | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\Calamansi 2.jpg  Extract | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\Calamansi 1.jpg  Calamansi | Pineapple | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Citrus\Citrus\pineapple 1.jpg  Pineapple |
| Popcorn | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\popcorn\Coffee\Coffee 1.jpg  Coffee | Image result for coffee  Coffee | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22894639_10207641807001941_1693814093_n.jpg?oh=e6582ce257891be58add212795fcb470&oe=59F64E92  Peanuts 1 | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22901502_10207641807081943_80482589_n.jpg?oh=f497fa0dc571ba354ddaa4664351b379&oe=59F6025B  Peanuts 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\popcorn\Coffee\Peanut Butter.jpg  Spread |
| Spread | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\popcorn\Coffee\Pili Nuts.jpg  Pili nuts | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22835260_10207641806841937_1274282559_n.jpg?oh=05d36773e9f7560f3f36415613c3f13b&oe=59F60942  Cashew | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\popcorn\Coffee\almonds 1.jpg  Almonds | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\popcorn\Coffee\almonds 2.jpg  Nuts |
| Sweet | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\Table Sugar.jpg  Sugar 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\White Sugar.jpg  Sugar 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\Coco Jam 2.jpg  Jam | https://scontent.farn2-1.fna.fbcdn.net/v/t34.0-12/22835392_10207641806881938_245843489_n.jpg?oh=88cad5defe2fda6ede36a8fd52fec1fd&oe=59F641D3  Honey | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\chocolate 1.jpg  Chocolate 1 |
| C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\chocolate 2.jpgChocolate 2 | Vanilla 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Vanilla 1.jpg  Vanilla 2 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Sweet\Brown Sugar.jpg  B. Sugar 1 | C:\Users\acer\Documents\Meanne\7 KTH 2\Dissertation Stuff\Photos of samples\Sweet\Brown Sugar.jpg  B. Sugar 2 |

**Table II Final Ann Confusion Matrix**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S** | **Fragrant** | **Woody** | **Fruity** | **Chemical** | **Minty** | **Decaying** | **Pungent** | **Citrus** | **Popcorn** | **Sweet** |
| 1 | 144 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 13 | 124 | 1 | 0 | 12 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2 | 0 | 147 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 1 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 148 | 0 | 2 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 71 | 6 | 44 | 17 | 12 |
| 7 | 0 | 0 | 0 | 0 | 28 | 4 | 83 | 0 | 24 | 11 |
| 8 | 0 | 28 | 1 | 0 | 2 | 17 | 0 | 102 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 136 | 13 |
| 10 | 0 | 0 | 0 | 0 | 0 | 4 | 28 | 0 | 30 | 88 |

**Table III Class Precision, Recall and F-Measure for the Different Odor Classes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Class** | **Precision** | **Recall** | **F-measure** |
| Fragrant | 0.960000000 | 0.905660377 | 0.932038835 |
| Woody | 0.826666667 | 0.784810127 | 0.805194805 |
| Fruity | 0.980000000 | 0.980000000 | 0.980000000 |
| Chemical | 0.993333333 | 0.993333333 | 0.993333333 |
| Peppermint | 0.986666667 | 0.778947368 | 0.870588235 |
| Decaying | 0.473333333 | 0.739583333 | 0.577235772 |
| Pungent | 0.553333333 | 0.691666667 | 0.614814815 |
| Citrus | 0.680000000 | 0.698630137 | 0.689189189 |
| Popcorn | 0.906666667 | 0.657004831 | 0.761904762 |
| Sweet | 0.586666667 | 0.709677419 | 0.642335766 |

**Table IV Mean Sensor Measurement per Odor Class**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S | Fragrant | Woody | Fruity | Chemical | Minty | Decaying | Pungent | Citrus | Popcorn | Sweet |
| 1 | 302.9 | 277.3 | 369.0 | 347.3 | 277.4 | 277.3 | 266.8 | 282.9 | 259.2 | 260.9 |
| 2 | 155.5 | 170.4 | 175.7 | 223.8 | 171.7 | 170.4 | 171.7 | 172.1 | 171.9 | 172.5 |
| 3 | 200.7 | 203.2 | 231.1 | 323.9 | 226.8 | 223.2 | 220.5 | 211.6 | 217.9 | 216.7 |
| 4 | 170.4 | 174.3 | 188.5 | 243.7 | 190.1 | 174.3 | 185.1 | 178.2 | 176.3 | 182.1 |
| 5 | 111.6 | 128.3 | 106.3 | 130.8 | 135.3 | 128.3 | 137.1 | 119.4 | 138.7 | 137.1 |
| 6 | 244.8 | 260.3 | 281.8 | 372.6 | 270.2 | 260.3 | 264.3 | 260.2 | 261.0 | 264.5 |
| 7 | 199.0 | 201.5 | 217.8 | 267.0 | 220.3 | 201.5 | 211.0 | 202.4 | 206.5 | 206.1 |
| 8 | 211.8 | 207.9 | 224.3 | 329.4 | 234.3 | 237.9 | 232.1 | 228.3 | 210.9 | 202.5 |
| 9 | 124.7 | 137.3 | 139.0 | 171.5 | 142.0 | 137.3 | 138.4 | 138.6 | 140.7 | 139.6 |
| 10 | 311.4 | 352.3 | 352.5 | 354.0 | 354.2 | 352.3 | 354.4 | 352.9 | 353.9 | 354.2 |

It can be noticed from Table IV that the classes with relatively inferior results (decaying, pungent, citrus, sweet) have several sensors with comparatively close measurements. For instance, about 12% of decaying samples were incorrectly classified as citrus, and this could be due to several sensor readings within close range (MQ3, MQ7, MQ8, MQ135, MQ138). The MQ-series gas sensors have partial sensitivity, i.e., that they can respond marginally to a range of gases, as listed in table Table V. MQ8 could marginally respond to alcohol and LPG, MQ135 has small sensitivity to ammonia etc.

**Table V Sensor Sensitivity**

|  |  |  |
| --- | --- | --- |
| Sensor | High Sensitivity | Partial Sensitivity |
| MQ 2 | Smoke | LPG, propane, hydrogen |
| MQ 3 | Alcohol |  |
| MQ 4 | Natural gas | Methane (CH4) |
| MQ 5 | LPG | Natural gas |
| MQ 6 | Butane, Propane | LPG, Natural gas |
| MQ 7 | Carbon Monoxide |  |
| MQ 8 | Hydrogen Gas | Alcohol, LPG |
| MQ 9 | Methane | Propane and CO |
| MQ 135 | Benzene | Ammonia |
| MQ 138 | Ammonia |  |