Supplementary Material

A Publication Count

To attain a rough order of magnitude of the proportion of research conducted on olfaction compared to other modalities, we queried both the Semantic Scholar [86] and ArXiv [38] websites as each has a large presence of machine learning research and convenient APIs from which we can query. We evaluated all papers from the period 1 January 2015 and 1 May 2025.

1. **ArXiv** For papers on ArXiv, we queried according to the ArXiv categories most relevant to each of the four topics. For computer vision papers, we queried all papers within the *cs.CV* and *eess.IV* categories. For natural language processing papers, we queried the *cs.CL* category. For speech and audio processing, we evaluated the *cs.SD* and *eess.AS* categories. Since there is no dedicated category for artificial olfaction, we queried for all papers whose titles contained any permutation of the words "olfaction", "olfactory", "smell", "odor", "odour", "scent".
2. **Semantic Scholar** For research submitted to the *Semantic Scholar* site, we perform a similar query strategy as above, except we search over the *physics, chemistry, biology, mathematics,* and *computer science* categories for each of the four topics.

We recognize that evaluation of only two databases is not comprehensive of all published research and/or funded projects, but we believe these two databases give a reliable order of magnitude from which we can evaluate the inequity of research attention in machine olfaction. Code to reproduce our queries is contained in the Github repository.

B Applications

Many applications for olfactory sensors exist. Some have room for improvement while others have yet to be realized. The below summaries give a brief overview of some high-potential applications within olfactory sensing, but is by no means comprehensive.

Robotics Companies such as Boston Dynamics [19], Tesla [149], Figure [58], and Clone [33] are building humanoid robots with the intent to distribute tens of millions to homes and factories within the next decade. Each of these robots has visual capabilities with cameras and lidar, audio capabilities through microphones and speakers, and built-in language models for human communication. The one modality none of them have exemplified, however, is olfaction. Olfactory sensors could massively benefit the robotics industry by enabling humanoids to detect harmful compounds, conduct regular breath analysis, and navigate by scent [25, 24, 54].

Agriculture Olfactory sensors monitor soil health by detecting volatile organic compounds (VOCs) emitted by soil microorganisms [28, 50]. They can also identify diseases early by sensing specific VOCs released by infected plants. This allows farmers and agronomists to take preventive measures, reducing crop loss and naturally improve yield without the use of harmful chemicals. Work by Barhoum, et al. [13] delineates challenges and opportunities manufacturing olfactory sensors for use in a ruggedized agricultural environment.

Food and Beverage Industry The quality and authenticity of wine and other beverages can be analyzed by their aroma profiles. Olfactory sensors can detect subtle differences in scent that indicate the presence of contaminants. This ensures product consistency and helps in identifying counterfeit products, protecting brand integrity. Work from Aryballe [7] exemplifies this with their olfaction sensors based on Mach-Zehnder interferometers. Similarly, research from Longin, et al. in [93] exemplifies how the analysis of aromas emitted from bread can indicate its shelf life; Wang, et al. in [143] demonstrate similar methods with pork freshness. These applications create a framework from which other food items can also be analyzed.

Indoor Air Quality Monitoring Olfactory sensors can be deployed in homes, offices, and public buildings to continuously monitor indoor air quality. They can detect VOC pollutants, mold, allergens, and harmful gases brought in from an external environment [72] that may go unnoticed by the human nose. Humans emit their own aromas as well [75] which could enable sensors to learn chemical signatures associated with each tenant. Most establishments have smoke detectors placed throughout, and advanced olfactory sensors could be deployed similarly. This contributes to healthier living and working environments by alerting occupants to potential air quality issues. Many applications within air quality monitoring already exist with opportunities for improvement [13].

Cosmetics & Perfumery In the cosmetics industry, olfactory sensors assist in the formulation and quality control of products such as lotions, creams, and deodourants. Work by Osmo AI [109, 108] gives a deeper look into this by demonstrating how olfaction can be combined with artificial intelligence to generate new cosmetics and quality control existing ones. This helps maintain product quality and consumer satisfaction and ensures that products have the desired scent profile and are free from unwanted odours.

Personalized Medicine In personalized medicine, olfactory sensors have been used to analyze breath or other biological samples to tailor treatments based on an individual's unique metabolic profile. Sensors can detect biomarkers for various conditions such as pneumonia [81, 12, 11] and lung cancer [3] providing insights into how a patient is responding to treatment. This enables more precise and effective healthcare interventions through non-invasive and cost-effective treatments.

Automotive Industry Olfactory sensors are being investigated in the automotive industry to monitor and control the air quality inside vehicles [138, 6]. The sensors have the potential to detect and neutralize harmful odours, enhancing the comfort and experience of passengers. Olfactory sensors can also be used to ensure that new car interiors meet quality standards for scent and to quality control vehicle parts for signs of corrosion [112] at the manufacturing plant.

C Objectivity

To demonstrate how human odour perception can be influenced by chemical compound and concentration, we construct an example of perception versus precision for two odorants associated with baked bread [93]: isovaleric acid [35, 76] and 2-acetyl-1-pyrroline [9, 79]. Most people begin to detect odourants at concentrations of 1 ppm or greater, with detection consistency increasing as concentration rises [97]. Modern olfactory sensors can sense concentrations well below the human threshold [32, 39, 68, 85].

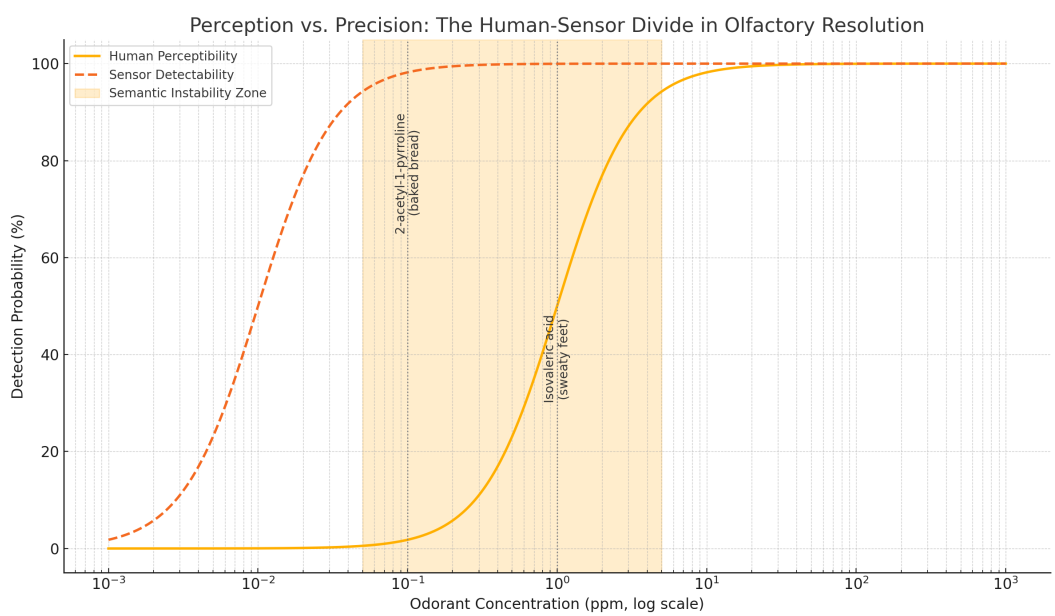

Figure 4: An example of perception versus precision in olfaction. The solid orange curve indicates human perceptibility [85]. The dashed orange curve shows sensor detectability. The shaded region marks a "semantic instability zone" around the perceptual threshold, where inconsistent smell labels introduce noise into datasets. Vertical markers highlight example odorants 2-acetyl-1-pyrroline (pleasant odour [9]) and isovaleric acid (unpleasant odour [35]) demonstrating how concentration alters interpretation.