デジタルオルファクション国際会議

8th DOS WORLD CONGRESS

DIGITAL OLFACTION SOCIETY

December 5 & 6, 2024
Tokyo, Japan

Abstracts & Demonstrations

8th Annual Meeting of

Digital Olfaction Society

December 5-6, 2024

Tokyo, Japan & Online

Jesús Lozano Rogado

President of Digital Olfaction Society

Marvin Edeas

Founder and Chairman of the Scientific Committee

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Welcome to the 8th DOS Congress

After the success of the five DOS World Congresses (Berlin, 2013 and Tokyo, 2014-2016-2018-2022) and the two congresses on Olfaction & Issues (Paris, 2010 and Milano, 2016), the scientific committee is pleased to welcome you to the 8th Digital Olfaction Society Annual Meeting which will be held on December 5-6, 2024, as a hybrid meeting: in Tokyo, Japan, & Online.

The DOS meeting is uniquely aimed at digitizing scents, transferring them, and re-creating them in different parts of the world. The two-day congress includes one day dedicated to talks and another day for demonstrations. Under the slogan "Olfaction to Digital Olfaction", the congress will explore the latest advances in olfaction science and digital olfaction technologies, highlighting their transformative impact across multiple fields.

We would like to thank all members of scientific committee, speakers and chairpersons of the Digital Olfaction Society for their contribution:

Moustafa Bensafi*, Université Claude Bernard Lyon 1, France*
Monica Bordegoni, *Politecnico di Milano, Italy*
Can Dincer, *Technical University of Munich, Germany*
Marvin Edeas, *Université de Paris, France*
Javier Gonzalez-Jimenez, *University of Malaga, Spain*
Shirong Huang, *Technische Universität Dresden, Germany*
Hiroshi Ishida, *Tokyo University of Agriculture and Technology, Japan*
Hamed Karami, *Institute for Bioengineering of Catalonia, Spain*
Meikei Lai, *Macao Polytechnic University, China*
Qi Lu, *Tsinghua University, China*
Santiago Marco, *Institute for Bioengineering of Catalonia, Spain*
Haruka Matsukura, *University of Electro-Communications, Japan*
Philipp Müller, *Tampere University, Finland*
Simon Niedenthal, *Malmö University, Sweden*
Marianna Obrist, *University College London, United Kingdom*
Kea-Tiong Tang, *Tsing Hua National University, Taiwan*
Ping Wang, *Zhejiang University, China*
Yasuyuki Yanagida, *Meijo University, Japan*

We hope that you will enjoy the DOS 2024 Congress and that your interactions with colleagues from many countries will stimulate a creative exchange of ideas and challenges

All the best,

Prof. Jesús Lozano Rogado
President of Digital Olfaction Society,
University of Extremadura, Spain

DOI Information

We are pleased to announce that the DOS 2024 Abstracts Book will be assigned a **DOI (Digital Object Identifier)**, ensuring a permanent and easily accessible online presence for the entire collection of work.

The DOI will be activated **after the congress**, and it will be communicated to all attendees.

How to cite your paper in the Abstracts Book?

To cite a paper presented at the DOS 2024 Congress, include the author's name, the conference date, the paper title (italicized), page number, the conference name, location, and DOI.

Citation example:

Smith, J. (2024, December 5-6). **Digital Olfaction: Revolutionizing the Science of Smell** . *p. 31*, DOS 2024 Congress, Tokyo, Japan. DOI

DIGITAL OLFACTION SOCIETY

8th Annual Meeting of

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8th Annual Meeting of

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Abstracts for Oral Presentations

Day 1 – December 5, 2024

DOS 2024 INTRODUCTORY REMARKS: DIGITAL OLFACTION: BIG CHALLENGES & HUGE BARRIERS

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In this introductory talk, we will explore the critical challenges and barriers confronting the field of digital olfaction as it advances toward real-world applications.

The multidisciplinary nature of digital olfaction requires collaboration among experts from diverse fields, including electronics, bioinformatics, biochemistry, biology, signal transmission, digitalization, and medicine. Bridging these disciplines remains a significant challenge to enable innovation and integration.

Key questions include:

1. Overcoming Barriers Across Disciplines: How can we improve collaboration between professionals from such diverse backgrounds and connect their efforts with policymakers and legal experts to create a cohesive framework for digital olfaction?

2. Encouraging Openness among Competitors: Many companies and researchers hesitate to share their innovations or participate in Digital Olfaction Society (DOS) meetings due to competitive concerns. How can we create an environment that supports trust, transparency, and mutual progress while respecting intellectual property?

3. Providing a Clear Vision for Startups: Numerous startups in this field are seeking clarity on the trajectory of digital olfaction to better position their efforts. How can we ensure a roadmap that integrates technological advances with societal, political, and legal considerations?

The talk will propose solutions to connect disciplines, encourage open dialogue, and engage policymakers and lawmakers in shaping the future of digital olfaction. By aligning technical innovation with societal needs and regulatory frameworks, DOS can play a pivotal role in overcoming these challenges and building a sustainable future for this field.

FIFTEEN YEARS OF DIGITAL OLFACTION: FROM PARIS 2010 TO TOKYO 2024

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Olfaction is generally considered as a minor sense, although in the food and beverage industry as well as in perfumery is undoubtedly the first one. Digital olfaction could also be considered as the third digital sense in terms of users and performance, after computer vision (Digital sight) and audio (digital ear). Unlike these senses, olfaction suffers from the phenomenon of olfactory fatigue (or olfactory adaptation), it's also important to realize that aroma chemistry is complex, and the smell of any scent is never really the consequence of a single chemical compound. All this makes the development of a digital olfactory system not an easy task.

The Digital Olfaction Society (DOS), founded in 2010 by Dr. Marvin Edeas, has led the difussion and promoted the development of digital olfaction technologies. This abstract reflects on 15 years of progress through DOS's conferences, which began in Paris (2010) and have continued in Tokyo (2016, 2018, 2022, and 2024). During these 15 years great advancements have been achieved in this field, such as sensor technology, electronics, artificial intelligence, olfactory displays, robotics, and applications, highlighting the evolution of digital scent.

Reflecting on Alexander Graham Bell's question, "Can you measure a smell?" DOS has made immense strides toward quantifying and replicating scents. Over 15 years, its conferences have showcased innovations transforming how we interact with and understand odors, creating new opportunities for healthcare, industry, and personal wellness. Our main idea is to promote this innovative concept whose aim is to turn any odorous source into digital media applicable to our lifestyle. As a matter of fact, the idea is to create devices which not only can record smells, turn them into digital data but also transmit and restitute them where we like.

In a few words, the objective of DOS is to gather, share, and complete the knowledge recently established about olfactory digitization. Our perspective is to build up constructive links between leading researchers and industrialists in order to set up appropriate strategies in order to implement Research & Development through practical applications with a high impact on our lifestyle thanks to the potential of olfactory digitization. We want to move from the Stone Age of odorous substance toward a New Age by means of digital fragrance, aroma and smell technologies. DOS gathers international researchers and academics, R&D departments in link with all the field of digital olfaction, chemistry, mathematics, physics, biochemistry, electronics, engineering, computer science, food and cosmetic industries, olfactory intelligent systems companies, marketing managers, investors and all other stakeholders in olfaction and digital olfaction industries in order to answer these questions.

The main challenges of the Digital Olfaction Society are: to update existing olfactory Research & Development (by highlighting the interdisciplinary sciences connected to the digital smell world and its related topics), to consider the practical applications of digital olfaction (the way in which we can transfer the recent scientific breakthroughs) and to project those applications to everyday life to measure their impact on our lifestyle.

IDENTIFYING CHEMICALS BASED ON ION AND DIFFERENTIAL MOBILITY SPECTROMETRY MEASUREMENTS

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Introduction: Ion mobility spectrometry (IMS) is a technique measuring drifting of gas-phase ions under the influence of electric field(s). Due to differences in the ions' molecular weights, charge, and the shape among compounds, their mobilities differ [1], resulting in different measurements for different volatile organic compounds (VOCs) emitted by chemical mixtures [2]. Therefore, unlike mass spectrometers, IMS can distinguish molecules with the same mass but different shape. One shortcoming is that IMS measurements provide no (direct) information on the composition of the measured mixture. Instead, the time series data from an IMS device can be interpreted as the mixture's fingerprint. Differential mobility spectrometry (DMS), also known as field asymmetric IMS, is an IMS separating ions by means of a separation field and a superimposed DC field. DMS measurements are, generally, represented in the form of images known as dispersion plots. Both IMS and DMS have been used for the identification of chemicals and chemical mixtures based on their emitted VOCs. This presentation provides a brief overview on our recent research, its results, and key findings.

Material & Methods: In [3,4], IMS responses from three chemicals at two flow rates as well as seven foods measured from headspace and ambient air were analyzed. For classification, a total of 19 classifiers in more than 300 configurations were embloyed. In [2], two IMS datasets of four foods measured from headspace and ambient air ensuring temporal and spatial variation between training and test datasets were collected and analyzed with an online classifier based on the K Neares Neighbors (KNN) approach. In [5], DMS responses to five chemicals measured from headspace at two concentrations and five flow rates were studied. For classification, six algorithms suitable for image and/or sequential data were tested.

Results: In [3], a simple KNN yielded high accuracy for identifying chemicals and their concentration levels as well as food odors based on IMS measurements. The analysis showes that also data from the transient phase can be used for identification, that concentration of a chemical alters its IMS fingerprint, and that enough time should be allowed between measuring two chemical mixtures for the IMS readings to return to the baseline. Accuracy levels of up to 99% were achieved in [4] by using Quadratic Discriminant Analysis, Multilayer Perceptron, C-Support Vector and Neural Networks. For DMS-based identification, interpreting DMS measurements as sequential data yielded in all tests highest or close to highest accuracy in [5].

Conclusion: Chemicals can be identified based on both IMS and DMS measurements using machine learning algorithms. However, changes in humidity level, temperature, and air pressure alter IMS/DMS measurements. Therefore, when collecting the measurements either measurement conditions need to be standardized or methods for mitigating the impact of changes in the environmental conditions should be used.

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OLFACTORY DIVERSITY: SUBTRACTIVE MIXING FOR VERSATILE ODOR CREATION

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Introduction: One of the major problems awaiting a solution in olfactory display research is the difficulty in odor synthesis. In vision, we can generate arbitrary colors by mixing three primary colors. This is because we recognize colors through the response pattern of the three types of photoreceptor cone cells and we can stimulate each type of cone cells indivisually using the corresponding primary color. On the other hand, we discriminate odors through 400 different olfactory receptor cells. Considering the overlapping specificities of the olfactory receptor cells, we may not be able to find primary odors each of which can indivisually stimulate a single type of olfactory receptor cells. However, a phenomenon called "olfactory white" was discovered[1], claiming that a mixture of about 30 diversely different chemical substances approaches a certain smell, as if the mixture of different colors always approaches white in vision. Inspired by this phenomenon, we proposed subtractive odor synthesis[2]. Considering the large number of components contained in a single smell (for example, hundreds of odorants are contained in coffee smell), it is difficult to synthesize a specific odor by adding chemical components one by one from scratch. However, there is a possibility that a wide range of odors can be generated by removing some components from the olfactory white. Here we report an odor reproduction system we developed based on this concept.

Material & Methods: Our odor reproduction system consists of an odor blender and an electronic nose (e-nose). We fabricated a 40-component odor blender that can mix vapor of up to 40 different chemicals at a specified mixing ratio. The 30 chemical components reported to evoke the olfactory white sensation[1] are set in the odor blender, and their vapor mixing ratio is adjusted so that the response pattern of an e-nose is matched to the response pattern to the given target smell. We chose Cyranose 320 from Sensigent having 32 gas sensors because most other commercial e-noses have only 8–16 sensors.

Results: We conducted odor reproduction experiments using eight commercially available flavors/fragnrances (banana, strawberry, grapefruit, green plum, hassaku orange, floral essence, elegant rose, and fresh green) as the target smells. Close match between the e-nose response patterns to the original and reproduced smells was attained for 7 out of the 8 flavors/fragrances tested. By checking with our nose, we confirmed that at least some features of the target smells were successfully reproduced in the synthesized smells, although the reproduced smells were not exactly identical to the target ones.

Conclusion: It is expected that presenting odors using olfactory displays will bring our virtual reality experience to higher levels. The proposed method provides a way to generate a wide variety of smells with a limited number of components. Future work will include attaining better match between the target and reproduced smells and trying a wider variety of smell synthesis.

Supported by: JST Mirai Program Grant Number JPMJMI22H4, JSPS KAKENHI Grant Number JP22K12124

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STOPPING TO SMELL THE ROSES: CAPTURING AND USING THE SCENTS OF EVERYDAY LIFE

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Introduction: Olfaction plays a pivotal role in emotions, memory, and sensory interaction. Starting with our "smell camera" prototype (DIS 2020) [1], we introduced a novel way to capture and replay real-world scents. This talk updates our exploration of physical odor capture, highlighting advancements like integrating sorbent tubes for improved portability and functionality, laying the foundation for future innovation. In line with our mission to support the olfactory research community, we also share our vision of fostering multisensory innovation in HCI.

Materials & Methods: We transitioned from airbag-based storage to compact, reusable sorbent tubes through iterative design. User-centered evaluations, including usability testing and diary studies, we conducted to inform the development process. Insights from toolkit projects like O&O [2] and Mul-O [3] guided exploration of modular and task-oriented olfactory systems.

Results: The compact sorbent tube-based design reduced prototype size and weight by 60% while enabling multi-scent playback. These improvements expand applications from memory preservation to immersive interactions.

Conclusion: Our advancements in olfactory interfaces enhance multisensory experiences and empower researchers and users. We envision olfactory interaction as a bridge connecting people, modalities, and intelligent systems, fostering innovation and collaboration in HCI.

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A TECHNOLOGICAL PROOF OF CONCEPT TO SUBSTITUTE OLFACTION IN PATIENTS WITH OLFACTORY LOSS

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Introduction: Losing one's sense of smell is not without effect on our daily lives: olfactory impairment affects many areas of life, from eating and sensory enjoyment to social life and hazard detection. To date, the main therapies are surgery, medication, or olfactory training, but a prosthesis-type technology enabling patients to sample their olfactory environment has not yet been developed. The aim of this study was to develop a proof-of-concept for such a device.

Material & Methods: The hypothesis tested in this work is that stimulation of the intranasal trigeminal system by a device that captures odorant molecules and transforms the chemical information into an electrical signal will enable patients to detect and discriminate odorant molecules via this alternative pathway. To test this hypothesis, a device combining an artificial nose and an electrical stimulator placed in the nasal cavity was developed.

Results: In the first part of the study, a series of experiments carried out on patients with olfactory loss, and on people with no olfactory loss, revealed that the proof of concept enabled 100% of volunteers to detect the stimulation, and that around two-thirds were able to discriminate between stimuli. In a second stage, we designed the proof-of-concept into a series of portable but non-functional prototypes, which provided us with valuable information on the acceptability of the future device and the points for improvement to be made to meet patients' needs and expectations.

Conclusion: Overall, this study should be seen as a demonstration of feasibility, with the next major step being to take user feedback into account in the design and functionalization of wearable devices, as well as to improve performance in terms of perceptual discrimination through appropriate training.

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CREATIVE COLLABORATION IN THE METAVERSE: THE EVOLUTION OF SCENT DESIGN

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Introduction: In recent years, virtual environments such as the metaverse have evolved from social and entertainment platforms to hubs for creative collaboration and innovation. Technology is becoming more integrated into multi-sensory virtual experiences, with olfactory displays widely utilized for this purpose [1]. For example, virtual environments and the simulation of scents present an exciting opportunity to revolutionize fragrance creation, enabling users to simulate, share, and co-create scents in digital spaces. However, despite the progress made in the field of eXtended Reality, the olfactory dimension remains underexplored in these immersive environments. This work aims to investigate the potential of virtual environments where users can share olfactory experiences, experiment with digital scent simulations, and collaborate to design new fragrances. This research intends to outline the opportunities and challenges of integrating olfactory experiences into the metaverse, providing a foundation for further exploration of sensory-based collaboration in virtual contexts.

Material & Methods: The goal of this research is to offer an educational and sensory experience within the metaverse, where visitors can share the journey with others, appreciate the intricate process of perfume creation, and actively participate as creators. This work adopts a mixed-methods approach, combining qualitative exploration with a conceptual framework for integrating olfactory experiences into the metaverse. The study developed a concept for a virtual perfume store on a selected metaverse platform, allowing participants to engage with simulated scent experiences and enjoy an immersive, memorable interaction [2]. The virtual perfume store features several virtual rooms dedicated to the main perfume note families: top notes, heart notes, and base notes. As visitors explore the virtual space, they will gain more profound knowledge about the art of perfumery and have the opportunity to select different fragrances for each note, allowing them to mix and create their personalized perfume. To simulate olfactory experiences, the metaverse leverages existing olfactory displays capable of evoking a range of fragrances [3]. The virtual environment and the experience have been preliminary tested by a group of participants, mainly consisting of students from the School of Design of our university, who were invited to enter the virtual space to explore, share, and design scents. Participants shared their thoughts and preferences through real-time interactions with others in the metaverse, contributing to the collaborative fragrance creation process.

Conclusion: The research aimed to evaluate the feasibility and user experience of olfactory interactions in the metaverse, highlighting opportunities and challenges in incorporating scent-based creativity into virtual spaces. Preliminary results indicate that integrating olfactory experiences into the metaverse offers significant potential for enhancing creative collaboration in the perfumery industry. Users reported high engagement and immersion when interacting with simulated scents in the virtual environment. However, challenges remain in accurately simulating complex scent profiles and ensuring consistent olfactory feedback across different devices used by various users throughout the metaverse. Overall, the study highlights both the opportunities for innovation and the technical limitations that need to be addressed for more widespread adoption of scent-based experiences in virtual spaces and metaverse.

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EXPANDING OLFACTORY SPATIAL DESIGN THROUGH MOBILE ROBOTICS

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Smell dances at the edges of recognisability. Hidden from view behind other sensory tones, olfactory undercurrents, crucial to orientation and navigation, rouse the antennae across species. The rise of immersive digital art venues usher in audiences who value ephemeral encounters of intensity augmented by scent.

Sensing systems for olfactory input/output display continue to evolve a vibrant field. Consumer digital technologies' affordability, size and power drive software and hardware innovation: scent teleportation, ambient scent marketing, e-noses, wearables, therapeutic devices, and cultural events. Correspondingly, odour plume visualisation and precise temporal resolution in robotics response (1). Despite these advances, dynamic scent display remains an underdeveloped channel. This situation makes spatial design challenging, especially when odour localisation, visualisation and digitisation are nascent (2). The objective is to create mobile robotics for performance spaces.

We present an olfactory wearable innovation that senses wearer biosignals, visualising data through wireless scent display (3). To validate the wearable, we tested usability in-performance in several venues. The findings suggest this approach provides an avenue to understand olfactory-somatic interaction challenges. Moreover, testing wearables in-performance maps dynamic materialities and architectures, systems benefit from biosignal input and olfactory output balance. Although frontier science was not the primary focus, multidisciplinary resources are essential for developers collaborating to expand mobile robotics for multisensory environments.

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QUANTIFIED TASTE DETECTION USING TASTE ORGANOID BASED ELECTRONIC TONGUE

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Introduction: With the rapid growth in food industry, there is an urgent need in digitalizing taste information to aid new product development. Traditional electronic tongues (E-tongues) based on chemical sensors, receptors, enzymes, molecularly imprinted polymers, or peptides have no intracellular signal processing and intercellular communications which are vital in the mammalian taste sensing process. [1] Taking advantages of the taste sensing elements from mammal, cell-based E-tongues can reveal real taste of samples from some respects. [2, 3] For example, lingual epithelium and its derived primary cells containing taste receptor cells which are responsible for primary taste recognition are used for sensing tastant molecules based on a microelectrode array or a light-addressable potentiometric sensor. These bioelectronic tongues demonstrate promising usages in the food industry and drug discovery. However, both lingual epithe-lium and its derived primary taste receptor cells have low lifespans and suffer from individual variabilities, which greatly impact their practicability and stability. Organoids are miniaturized organ models formed in vitro using pluripotent stem cells or adult stem cells. They highly resemble the native organ in terms of gene and protein expression, metabolic function and microscale tissue archi-tecture. More importantly, the extracellular niche used for organoid culture mimicking the in vivo environment allows the stem cells in the organoid to constantly renew them-selves while maintaining their capability to differentiate into the multiple cell types of their tissue of origin. [4]

Material & Methods: In this study, to mimic the biological sense of taste ex vivo, we developed a bioelectronic tongue based on bioelectronic organoids. In the E-tongue, the microelectrode array (MEA) functioned as gustatory axons to receive gustatory information by real-time recording the extracellular potentials of on-chip taste organoids. Thanks to the self-renewal activity of taste progenitor cells and the ability to differentiate into different TRCs, the taste organoids maintained key taste receptors expression after the third passage and maintained high cell viability during on-chip culture. To further improve the life span of the device, we utilized extracellular vesicles derived from natural killer cells (NK EV) as antimicrobial elements and developed a microfluidic system for practical sample detection. The microfluidic system enabled antimicrobial substances delivery, culture medium supply, and sample injection.

Results: The taste organoid based electronic tongue not only distinguished sour, sweet, bitter, and salt stimuli with high specificity, but also recognizes varying concentrations of the stimuli. Then, the E-tongue was used to quantify the taste information of lemon juice and the results showed that the E-tongue was able to calculate the degrees of sour, sweet, bitter, and salt of the lemon juice.

Conclusion: It is hoped that this bioelectronic tongue can facilitate studies in food quality controls, disease modelling, and drug screening.

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AI-ENABLED LOW DIMENSIONAL MATERIALS-BASED ELECTRONIC OLFACTION SENSORS AND THEIR APPLICATIONS

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Among our five human senses, sight, hearing, and touch have been highly digitized, while smell and taste remain in the nascent stages of digitization. Inspired by the biological example, gas sensors in combination with efficient machine learning algorithms aim to achieve similar performance and thus to digitize the sense of smell. Despite the significant progress of e-noses, their compactness still remains challenging due to the complex layout design of sensor arrays with a multitude of receptor types or sensor materials, and the high working temperature. In this talk, we present the development of machine learning-enabled graphene-based single-channel electronic olfaction (e-olfaction) sensors and propose a methodology to evaluate their olfactory performance. We selected four VOC-based odors, namely eucalyptol, 2-nonanone, eugenol, and 2-phenylethanol, which are widely used in human olfactory performance assessment. We achieved a low odor detection limit of 4.4 ppm (for 2Phe) and high odor discrimination (83.3%) and identification (97.5%) accuracies. Both molecular dynamics simulations (MDS) and density functional theory (DFT) were employed to elucidate the adsorption interaction between odorant molecules and sensing materials. Our work demonstrates that the developed e-olfaction exhibits excellent olfactory performance in sniffing out VOC-based odors. This work could facilitate miniaturization of e-noses, digitization of odors, and distinction of volatile organic compounds (VOCs) in various emerging applications, such as molecular discrimination, food quality identification, disease diagnosis, *etc*.

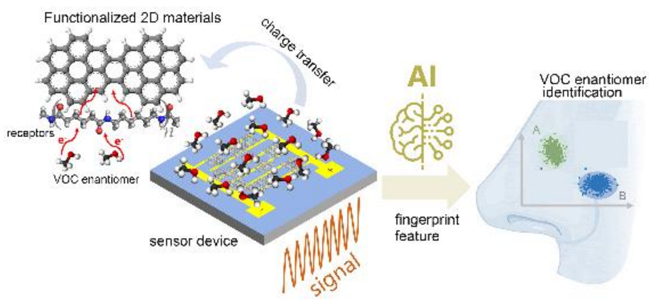

Fig. 1 Scheme concept of electronic olfaction sensors

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OPPORTUNITIES AND CHALLENGES FOR DRONE-BASED ODOUR MONITORING: DEVELOPMENT AND MAINTENANCE OF CALIBRATION MODELS

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Introduction: Waste Water Treatment Plants (WWTP) often produce offending odours for nearby residents. Those odours decrease their quality of life, and they can produce headaches, stress and anxiety. In Europe, standardized methods for the evaluation of the intensity of this odours are very well accepted (EN13725). Since the standard is based in human panels using sophisticated dynamic olfactometry, odour evaluation becomes expensive, unfrequent, slow and spatially sparse. Instrumental Odour Monitoring Systems (IOMS) have been proposed as an alternative to provide continuous montoring in fixed locations. In recent years we have explored the opportunities open by IOMS mounted on drones.

Materials & Methods: We have developed an in-house chemical sensor array system (RHINOS) that containts 16 Metal Oxide Sensors, five electrochemical sensors and one infrared CO2 sensors. The unit features wireless communications to a base station, and it is able to control a sampler for calibration purposes. The unit flies in a DJI 600 octocopter, featuring a 10m long tube to avoid the influence of downwash at the sampling location. With this system we have made field campaigns in four different WWTP. We have addressed the problems of odour detection, odour quantification and odour source identification.

Results: We have developed a workflow for online signal processing and pattern evaluation capable of odour characterisation. Odour detection achieves accuracies over 95% for odour intensities exceeding 200 ou_E/m^3. Odour quantification is unbiased but it features multiplicative uncertainties up to a factor of 4 (al 95% CI), compared with a factor of 2 (95% CI) for human panels. Class specific odour quantification prediction models surpass the performance of general models, but their use is limited to cases where the drone is in proximity to the source. This is due to the fact that odour source identification is often unreliable.

Conclusion: IOMS mounted on drones offer promising opportunities for odour evaluation and mapping in Waste Water Treatment Plants, however the maintenance of calibration models remains an open challenge.

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GAS SOURCE LOCALIZATION WITH A MOBILE ROBOT

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Locating the origin of a gas leak using an autonomous mobile robot is challenging due to two main reasons: the limitations of current chemical sensors (e-noses), which typically provide only single-point measurements that are heavily affected by errors, and the intricate nature of gas dispersion in the environment, which may involve numerous inlets and outlet points and be obstructed by obstacles.

This presentation will examine these limitations and explore some of the latest solutions available.

OE ORGANOID-BASED BIOMIMETIC OLFACTORY SENSOR FOR ODOR DETECTION

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Introduction: The mammalian olfactory system is considered to be one of the most efficient chemosensing system due to its extraordinary ability in odor detection. The olfactory sensory neurons (OSNs) in the olfactory epithelium (OE) regenerate throughout the life of mammals. However, diseases or injury, such as allergies, head trauma, nasal polyps, neurodegenerative diseases and COVID-19, often cause varying degrees of olfactory dysfunction including hyposmia and anosmia. In general, olfactory dysfunction affected by inflammation or a polyp will resolve after medication or surgery, but when it is caused by nerve damage, it might be permanent and lack treatment. The development of bioinspired olfactory biosensing technology makes it possible to mimic biological olfactory system.

Material & Methods: 3D culture technique was used to induce mammalian olfactory epithelial stem cells to differentiate into OE organoids. In order to initially demonstrate the presence of mature OSNs in the OE organoids and its ability for odor perception, immunofluorescence staining and calcium imaging were performed. MEA is one of the most important biosensors and has been commonly used to detect extracellular electrophysiological activities of cells cultured in vitro due to its long-term and non-invasive features. However, due to the three-dimensional structure of organoids, there are many difficulties to be overcome in applying MEA to organoid electrophysiological detection. One of the most critical is to ensure precise and stable contact between the organoids and the electrodes. Therefore, a multiwell microelectrode array (MEA) chip was designed and processed to acquire and record the odor response signals of OE organoids. Then the feature extraction and pattern recognition of the signal are completed by the neural decoding algorithm, and then the odor recognition model is constructed to realize the high sensitivity, specificity, stability and rapid detection and recognition of the odor.

Results: Owing to the advancement of three-dimensional cell culture technology, stem cell-derived organoids are generated, which have certain cellular composition and physiological features in common with real organs. After about 2 weeks culture, olfactory marker protein (OMP) expression can be detected by immunofluorescence which marks the maturation of OSNs. When the organoids are transferred and fixed to the MEA chip and given specific odor stimuli, the corresponding signal of neural activity is recorded. The spatial and temporal patterns of neural activities in the organoids, including spike and local field potential, provide reliable information specific to odors and their concentration. The results have indicated that the changes in LFP oscillations of OE organoids and OE tissue following odor stimulation were highly similar, both displaying a dramatical increase in delta power.

Conclusion: In this study, we cultured functional OE organoids induced from olfactory basal stem cells. OMP, the marker for mature OSNs, was observed in the OE organoids by immunofluorescence staining. Based on the functional OE organoids and the MEA system, the biomimetic olfactory sensor towards modeling the olfactory system in vitro was constructed. Both spontaneous activities and odor-evoked response were recorded by the system. Collectively, this work demonstrates the ability of the OE organoid-based biomimetic olfactory sensor to recognize odors specifically. The biomimetic olfactory sensor provides a new in vitro model for investigating the mechanisms and treatments of olfactory dysfunction.

TRANSCENT THE EDUCATION: DESIGNING VR MEDITATION THROUGH DIGITAL INCENSE FOR THE YOUTHS

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Introduction: The youths in East Asia are facing different degrees of stress in education nowadays. Virtual Reality (VR) has emerged as an alternative approach to the traditional therapy for anxiety and depression. Conducting meditation in virtual environment could foster positive emotions and wellbeing improvement. Many Olfactory VR (OVR) studies focus on using oil-based or liquid-based scent materials along with wearable olfactory display to provide individual olfactory experience. However, there are many challenges behind. The weight of OVR displays and the leaking issues of the scent cartridges might not be suitable for meditation practices. Incense has a long history for meditation and therapy. It could create a warm and cozy atmosphere in the space within a short time. The aim of this research is to open the dialogue about the contexts and scenarios in which meditation practices through digital incense can be applied. It proposes to take digital arts as the form for the youths to have inner dialogue through olfactory sensory experience.

Material & Methods: *TranScent* is a series of experiments exploring the possibility of supporting the youth's wellbeing through digital olfactory technology with incense. It includes three phrases: Phrase (i) Taking the sensory ethnography fieldwork in the real world; Phrase (ii) Experiencing VR meditation with incense aroma, and Phrase (iii) Turning into an artwork showcased in public space. In Phrase (i), students were encouraged to explore their living community through sensory ethnography fieldwork. In Phrase (ii), we designed the incense hub which includes an incense tray connected to VR. The system would be activated when the user reaches to certain scenes in the virtual environment. By placing different types of incense sticks on the tray, user could decide the sequence of incense aroma to accompany the meditation. The participants were recruited from an undergraduate school in Macao, aged 18 to 25 years old. The purpose and the guideline were given prior to the study. After completing the experience session, the participants were invited to fill the questionnaire about their mediation quality and overall experience. In Phrase (iii), we turn the incense hub into an artwork installation and showcased in the public space on campus.

Results: The participants responded that the sensory ethnography fieldwork helped them discover the unexpected and interesting aspects of their community. The olfactory experience of *TranScent* let them immerse in the virtual environment, helping them to relax and release the tiredness. However, some participants noted that it was difficult to distinguish the incense aromas after a while. One participant expressed the desire to lie on the floor to experience *TranScent*, which is just like lying on grass to meditate.

Based on the observation, we found that some participants kept sniffing when exploring in the virtual world. They approached it like a VR game and felt eager to identify the incense during the experience.

Conclusion: *TranScent* demonstrates that it provides users an alternative way to meditate with the incense while immersing in a virtual environment. It is importance to provide certain mediation steps as guidelines within the virtual scenery for the users to go through the process. It might help the user to focus on the meditation rather than the identification of incense. In the future, it is suggested to be employed in the real living environment to explore the possibilities for daily life.

Supported by: This research is funded by Macao Polytechnic University (Research Project Code: RP/ESA-02/2021).

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NAVIGATING THE CHALLENGES AND POTENTIALS OF E-NOSE IN HEALTHCARE AND FOOD SECTORS

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Introduction: Electronic nose (E-Nose) technology represents a significant advancement in healthcare and food safety, offering the capability to detect illnesses through body odors and ensure food freshness. This paper aims to explore the potential and challenges of E-Nose applications, focusing on three core areas: challenges, opportunities, and a forward-looking vision. The purpose is to provide a comprehensive overview of the current state of E-Nose technology and its future prospects in revolutionizing diagnostics and food quality assurance.

Material & Methods: This study employs a comprehensive literature review and analysis of current E-Nose technologies, their applications, and limitations. The research focuses on:

1. Examining the technical challenges in E-Nose development, including selectivity, sensitivity, and interference suppression.
2. Analyzing current applications in healthcare and food safety sectors.
3. Evaluating emerging trends and future directions in E-Nose technology.

Results: The results of our analysis reveal several key findings regarding E-Nose technology. In terms of challenges, the technology faces significant hurdles in selectivity and sensitivity, particularly when detecting low-concentration compounds within complex mixtures. Interference from non-target odors poses a substantial threat to accuracy, highlighting the need for robust filtering mechanisms. Additionally, the development of effective feature engineering and odor identification methods remains crucial for enhancing E-Nose performance [1]. Despite these challenges, E-Nose technology presents remarkable opportunities across various sectors. In healthcare, it shows promise for early disease detection through non-invasive breath analysis, potentially revolutionizing diagnostic procedures. The food industry stands to benefit from enhanced safety protocols, with E-Noses capable of swiftly and accurately detecting spoilage and contaminants [2].

Looking to the future, several promising prospects emerge. Advancements in sensor technology are expected to improve selectivity and sensitivity, addressing current limitations. The integration of machine learning and artificial intelligence holds potential for enhancing feature extraction and odor identification capabilities. Furthermore, the trend towards more compact, portable, and user-friendly E-Nose devices suggests a future where this technology becomes increasingly accessible and widely applicable across various fields [3].

Conclusion: While E-Nose technology faces significant challenges, its potential to transform healthcare diagnostics and food safety is immense. The technology is poised to usher in a new era of smell-based analytics, offering innovative solutions to pressing health and safety concerns. Future success hinges on interdisciplinary collaboration and continued advancements in sensor technology and data analysis techniques. As E-Noses become more sophisticated and accessible, they have the potential to revolutionize personal health monitoring and food safety practices, bringing odor analysis capabilities directly to consumers and healthcare providers.

This research is supported by the Digital Olfaction Society (DOS) and the Institute for Bioengineering of Catalonia (IBEC).

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BIONIC OLFACTORY SENSING AND DIGITAL RECOGNITION ALGORITHM

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Introduction: Odor detection has significant scientific and socio-economic value in improving quality of life and ensuring human health. Bionic olfactory sensing technology seeks to advance conventional methods by employing functional biological materials as sensitive elements, which can produce specific responses. These responses are then converted into readable signals through sensors, thereby achieving a chemical information transmission and recognition process similar to that of biological sensory systems. The incorporation of artificial intelligence algorithms enables real-time monitoring and adjustment of sensing signals, and subsequently enhance the accuracy, reliability, and responsiveness to dynamic environments.

Material & Methods: Utilizing 3D cell culture technology, we facilitate the differentiation and proliferation of murine Lgr5+ basal cells in vitro, leading to the formation of organoids that replicate the structure and function of olfactory epithelium. This approach yields sensitive materials that more closely resemble biological olfactory organs. Concurrently, we developed viral vectors harboring olfactory receptor genes for the purpose of targeted odor detection, which are subsequently transfected into olfactory cells or organoids. This process enables the expression of specific olfactory receptors, thereby conferring odor specificity.

On the other hand, we recently developed the olfactory brain-computer interface by integrating living mammals with implantable flexible neural electrodes, crucially involving the real-time and precise capture of brain electrical signals related to specific odors from the olfactory regions of animal brains, thus facilitating the recognition and classification of odors.

Results: Through feature engineering, key temporal and spectral features were extracted from the LFP signals, several machine learning algorithms were applied for classification, with the linear discriminant analysis model performing best in the smell classification task, reaching an accuracy of 84.9%. Furthermore, deep learning models based on one-dimensional convolutional neural networks and long short-term memory networks achieved higher classification accuracies of 88.6% and 91.2%, respectively.

Moreover, a novel distance indicator based on a spiking neural network (SNN) that integrates multiple sensors is proposed. This method effectively utilizes sensor arrays to estimate source distance, with an average root mean square error (RMSE) of less than 0.1 m across different wind speeds, outperforming single-sensor-based indicators. The model exhibits good distance estimation performance within a relatively short detection time, with an average RMSE of 0.118 m.

Conclusion: This bionic olfactory sensing technology demonstrates significant potential for application in environmental monitoring, food safety, disease diagnosis, and beyond.

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OLFACTORY INTERFACES FOR SMELL TESTING AND TRAINING: INNOVATIONS FROM A HUMAN-COMPUTER INTERACTION (HCI) PERSPECTIVE

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The sense of smell, while fundamental to our sensory experiences, has often been underutilized in digital technologies. This talk explores the intersection of Human-Computer Interaction (HCI) and digital olfaction, highlighting recent advancements in olfactory interfaces. These innovations are transforming smell testing[1] and training[2] in both professional healthcare settings and private home environments. By incorporating advanced sensory technologies into digital platforms[3,4], HCI research is paving the way for richer multisensory interactions.

This talk will showcase the latest developments in olfactory interfaces and discuss their potential to enhance digital health and wellbeing[5].

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FAST ASSESMENT OF ODOR CONSTITUENTS IN WASTEWATER TREATMENT PLANTSUSING ION MOBILITY SPECTROMETRY COMBINED WITH BLIND SOURCE SEPARATION TECHNIQUES

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Introduction: This study explores the use of Ion Mobility Spectrometers (IMS) for odor monitoring in Wastewater Treatment Plants (WWTP). IMS offers advantages like portability, rapid response, and high sensitivity for detecting volatile organic compounds (VOCs). However, the complexity of multiple odor sources in WWTPs complicates odor evaluation. Blind source separation techniques can enhance the extraction of chemical information from IMS data.

Materials & Methods: We used the GDA2 IMS (AIRSENSE Analytics) to detect VOCs and generate mobility spectra, acting as unique gas fingerprints. Data was collected at 46 locations in the Pinedo WWTP in Spain, categorized as 'water' and 'sludge'. Our aim was to analyze these molecular fingerprints and extract VOC concentration profiles using Multivariate Curve Resolution - Least Absolute Shrinkage and Selection Operator (MCR-LASSO).

Results: The MCR-LASSO method decomposed each sample into time concentration profiles and multi-modal mobility spectral profiles due to ion correlation. To obtain a single spectrum per ion, Gaussian unimodal spectra were generated. Final concentration profiles were then derived by applying a Least Squares approach to the original data and unimodal spectra, revealing differences between the two sample classes.

Conclusion: Our methodoly succesfully extracted concentration profile information for ions from IMS data collected from WWTP samples.

This project has received funding from ATTRACT project (grant No. 101004462) and IBEC-CERCA.

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LACTOBACILLUS METABOLITES BIOMIMETIC COMPLEX UPREGULATES OLFACTORY RECEPTOR-MEDIATED WOUND HEALING IN SKIN CELLS

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Olfactin® is a fermentation platform that uses bacteria strains that enhances the volatile organic compounds (VOCs) in plant extracts. Lactobacillus metabolites (LM), is a rose extract complex that contains more than 300 metabolites.

This study aimed to investigate the effects of a biomimetic Lactobacillus Metabolite Complex (LM) on wound healing in HaCaT cells (1). HaCaT cells were cultured in a 24-well plate and a scratch wound was created. The cells were then treated with LM, a positive control (PC), or a combination of LM and Oxyphenylon (an OR2AT4 antagonist). Wound healing was assessed using ImageJ software to measure the recovery area over time. Additionally, cAMP levels were measured in HaCaT cells treated with LM, Oxyphenylon, or both to evaluate the activation of OR2AT4.

The results demonstrated that LM significantly accelerated wound healing compared to the control group. Similarly, the positive control (PC) also showed enhanced wound healing. Treatment with LM resulted in higher wound healing rate compared to positive control. However, co-treatment with Oxyphenylon inhibited the wound healing effects of both LM and PC. Furthermore, LM was found to induce a concentration-dependent increase in cAMP secretion, which was significantly blocked by Oxyphenylon. These findings suggest that LM promotes wound healing in HaCaT cells through the activation of OR2AT4. By binding to OR2AT4, LM triggers an increase in intracellular cAMP levels, leading to enhanced cell proliferation and accelerated wound healing. This study provides valuable insights into the potential therapeutic applications of LM in wound healing and highlights the importance of OR2AT4 in this process.

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SELECTIVE OLFACTORY RECEPTOR MODULATION OF A SANDALWOOD COMPLEX ALLEVIATES ATOPIC DERMATITIS SYMPTOMS: A PRELIMINARY TRIAL REPORT

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Atopic dermatitis (AD) is a chronic inflammatory skin condition characterized by pruritus, skin barrier dysfunction, and heightened immune responses. Emerging evidence suggests that olfactory receptors (OR) play a role in keratinocyte proliferation, skin barrier repair, and anti-inflammatory responses. Sandalwood bioactives are previously shown to have a modulatory effect on ORs. But most AD patients experience exacerbation of symptoms after oil applications. Hence, we developed a unique Sandalwood Matrix that can be used with a diffuser to specifically target the ectopic ORs in the skin.

A double-blind, placebo-controlled study was conducted with 24 participants diagnosed with mild-to-moderate AD. Participants were randomized into OSM treatment and placebo groups. Clinical parameters, including SCORAD scores, skin hydration, and TEWL were assessed at baseline and 8 weeks. Inflammatory markers and mRNA expression levels of OR10G7, OR2AT4, and filaggrin were analyzed in skin biopsy samples.

The OSM treatment led to significant improvements in SCORAD scores and a marked reduction in inflammatory cytokines. Skin biopsy analyses revealed significant modulation of OR expression, suggesting a novel mechanism of action. These findings highlight the potential of olfactory interventions for the management of AD.

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ODOR PLEASANTNESS RECOGNITION BASED ON MOLECULE SPACE – GRAPH CONVOLUTIONAL NETWORK

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Introduction: Odor molecules induce olfactory experience by binding to the olfactory receptors, where the molecular structure plays a significant role. Traditional molecular structure analysis mainly focuses on two-dimensional representation, containing relatively limited information. While this study explores three-dimensional spatial characteristics of molecules to analyze the odor-induced pleasantness.

Material & Methods: Two hedonic odor molecule datasets were established by assigning pleasant or unpleasant labels based on a Screening Fragrance (SF) database [1] and the Dream Olfaction Prediction Challenge (DOPC) [2]. To identify molecule pleasantness, 1) three-dimensional atomic space coordinate features were extracted and a preprocessing strategy to address cross-molecule spatial discrepancies was proposed; 2) a molecule space - graph convolutional network was developed.

Results: For the SF database, train and testing sets were randomly divided in an 8:2 ratio, and a testing accuracy of 81.25% was achieved. For the DOPC database, the testing model is the same as that in SF dataset, and an accuracy over 70% was obtained, superior to the multilayer perceptron, graph convolutional network, and graph attention network.

Conclusion: A relationship between odor molecules and pleasantness perception is effectively established by mining molecular spatial structure information, which lays a certain foundation for digital olfactory at the molecular level.

Supported by: the National Natural Science Foundation of China (Grant No. 62203321, 22208080).

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DIGITAL OLFACTION SOCIETY

NEW AROCHEMBASE SOFTWARE 2024
THE MISSING LINK BETWEEN ODOR / AROMA AND CHEMICAL ANALYSIS

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AroChemBase: Comprehensive Odor & Chemical Analysis Database

Introduction

- What is AroChemBase? It is a powerful software solution designed for chemical and odor analysis, specifically tailored for gas chromatography (GC-FID) and gas chromatography-mass spectrometry (GC-MS) applications, also very useful for (GC-O) users.
- Purpose: AroChemBase software provides a comprehensive library of compounds, facilitating accurate identification, advanced analysis, and enhanced decision-making across industries.
- This library gathers a comprehensive collection of odor/aroma-related resources in one place, not limited to chemical analysis.

Examples:

- Investigate compounds that smell like ...
- Search for publications where any odor/aroma compounds are reported
- Investigate the concentration at which any odor/aroma compound is perceived

Key Metrics

- 188,000 Compounds cataloged for diverse chemical applications.
- 4,000 Compounds with odor data, including 600 specific aroma attributes.
- 1,820 Compounds with human smell detection thresholds for precise odor analysis.

Main Features of AroChemBase Software

1. **Multi-Parameter Search Mode**
   - The software allows users to search compounds by multiple criteria (e.g., name, CAS number, molecular formula, molar mass, odor descriptors, application field, retention index, odor perception threshold).
   - It displays search results in an organized list format with in-depth details on each compound, enhancing the user's ability to find and analyze relevant data quickly.
2. **Identification Mode**
   - **Peak Analysis**: Upon importing a chromatogram, AroChemBase software calculates Kovats indices for each peak, streamlining compound identification.
   - **Interactive Identification**: Hovering over peaks reveals potential compounds, with detailed pop-ups providing retention times and other characteristics, enabling faster analysis.

Applications and Use Cases

1. **Aroma and Odor Profiling**
   - Ideal for industries focused on flavor and fragrance, aiding in detailed aroma profiling.
2. **Chemical Characterization and Quality Control**
   - Supports accurate identification, critical for regulatory compliance and consistency in product batches.
3. **Odor Benchmarking**
   - Establishes odor standards for competitive analysis and improvement.
4. **Product Development**
   - Facilitates re-formulation, reverse engineering, and optimization within product development cycles.
5. **Shelf-Life Analysis**
   - Monitors chemical transformations over time, providing insights into product stability and shelf-life prediction.

Technology Highlights

- Kovats Index Matching: AroChemBase software matches chromatographic peaks against the Kovats index database for accurate compound identification.
- Compatibility: Integrates with major GC-FID and GC-MS systems (Agilent, Perkin Elmer, Shimadzu, Thermo, and Varian Bruker).
- Multilingual Support: Available in multiple languages for global accessibility.

Conclusion

AroChemBase software is an essential tool for professionals requiring detailed chemical and odor analysis. With its advanced features, it supports industries in quality control, product innovation, and regulatory compliance.

SCENTS AND SONICS OF THE OCEAN: MULTI SENSORIAL TRACES OF LOST AND RECOVERED MEMORIES OF SAPELO ISLAND

HAN, Yosh

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Introduction: Malte Leander (sound composer), Julia Kubanek (Professor, Researcher and Scientic Author at University of Georgia) and Yosh Han (perfumer), met at an Ocean Memory Project Seed 3 conference on Ocean Memory Loss at the University of Georgia Marine Institute, Sapelo Island, Georgia where a group of thinkers spanning divergent scientific, artistic and other creative practices came together to broaden an understanding and awareness of all ways in which the ocean may retain, express, and lose memory. The focus was on the topic of memory loss, particularly in relation to system processes and human memory including the importance of historical and current-day human populations on Sapelo Island; the rich Gullah-Geechee culture; the geological history of barrier islands; the role of chemical signaling in marine ecology and the role of story-telling and science writing in ocean science communication.

Material & Methods: A total of three scent accords, representing diferent geological zones - "MARSH," "FOREST," and "COAST" were developed by Yosh, blended to create a multisensory "scented snapshot". Rather than try to replicate a realistic odor profle, she tried to imagine the idea of these aromas, in combination with wind, over time, hundreds of years and the remoteness of the island, with and without human interaction. Some of the aromas are odors that are not actual plant materials found on the island but rather, evoke an element of these spaces. The molecules that make up the scents of Sapelo Island each have a particular chemical structure, composed of atoms bonded together in specfc shapes. In drawings of these molecules, lines represent the bonds between atoms, with carbon atoms at the intersection of each line. All molecules have hydrogens attached to the carbons and some molecules have oxygen atoms (“O”). Atoms have a property called “nuclear spin” that resonates at a specifc frequency in a strong magnetic feld, recorded in the lab by a nuclear magnetic resonance (NMR) spectrometer. The NMR spectrum has peaks depicting the resonance frequency of each atom. The pattern of peaks is used to determine the chemical structure of each scent molecule and then reported in the scientifc literature. The NMR spectra have been processed through the method of sonifcation and musifcation. Here, the peaks of the spectra are extracted through a graphic notation software in order to have them dictate how the soundscapes are built and transcribed. Layered with this material are field recordings captured around the various environments of Sapelo Island. Using an image-to-sound converter, the NMR spectra can also be used as the actual waveforms of the synthesized sounds that make up the layers of the soundscapes. The fnal musical result is therefore dictated by the spectra in various ways; by acting as the sound source itself, by having the peaks and dips determining the changes in pitch over time, and through other cross-modulation techniques between sounds. What you hear is an accumulation of a number of sonifed NMR spectra of scent molecules corresponding to each scent accord. The frequency data from the spectra were used as inspiration for composing sonics representing the three perfumes.

Results: "COAST" smells of the Atlantic Ocean, delta waters, shell rings, horseshoe crabs, seaweed, and coastal aromas. “MARSH” depicts aromas of sulfur, salt marsh, dunes, cordgrass and wet soil. The “FOREST” fragrance is inspired by the landscape with cabbage palmetto trees, holly, magnolia, sparkleberry, slash pine, live oaks, moss, cedar, and wax myrtle. The sounds were composed based on the data and presented as sound loops for the audience to smell and listen to the composition simultaneously.

Conclusion: We presented the final project to our academic and art peers as well as to the public-at-large. We had many requests for similar multi-sensorial projects for other cities, destinations and environs, especially ecologically sensitive areas. Currently, the author/perfumer has a 3-month residency in 2025 with 836M, based in San Francisco, with a different sound composer and tactile artist. The project scope is yet undefined other than it will be multi-sensorial and multi-disciplanary. There is much desire and demand for the olfactive community to partner with scientists and artists in other fields to further the olfactive arts.

Supported by: this project is funded in part by THE OCEAN MEMORY PROJECT THROUGH A GRANT FROM THE NATIONAL ACADEMIES KECK FUTURES INITIATIVE NAKFI-CA01. This project was also on display at an exhibition hosted by the Institute for Art and Olfaction for a period of 3 weeks in January, 2024.

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2. Scents and Sonics of the Ocean: Sound Scapes by Mlate Leander
3. Scents and Sonics of the Ocean: Photos from Gallery Exhibition

TRANSRATING IMAGES INTO ODORS

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Introduction: Odor technology, combined with artificial intelligence (AI) and digital transformation (DX), has the potential to revolutionize sensory experiences. Revorn, a Japanese startup, introduces a unique system that transforms images into scents, contributing to the democratization of the sense of smell.

Material & Methods: Our proprietary system consists of three components: (1) the Aroma Engine, a cloud-based platform for generating scent recipes from image inputs, (2) the multi-port diffuser, capable of precise scent reproduction using interchangeable aroma cartridges, and (3) olfactory impression scoring algorithms that predict scent profiles. During the demonstration, uploaded images are analyzed to generate scent recipes, which are reproduced in real-time by the diffuser.

Results: The system successfully converted various images, such as landscapes and abstract art, into distinct scents. The diffuser loaded with eight aroma cartridges, recreated olfactory impressions with high precision. Existing customers feedback highlighted the system's innovative potential for creative and industrial applications.

Conclusion: Revorn's technology bridges visual and olfactory senses, offering new possibilities in art, marketing, and consumer experiences. This integration of odor technology with AI and DX paves the way for a new era of sensory engagement.

MINIATURE WEARABLES FOR DIGITAL OLFACTION LIVE DEMONSTRATION

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Figure 1: Smart pendant

An innovative smartwatch and smartpendant with digital olfaction capability and wireless communication via Bluetooth® Low Energy 5.3 is presented. This embedded system integrates a microcontroller designed to have an extremely energy efficiency based on a 32-bit RISC Arm® Cortex® - M4 core (CPU1) and in a high performance. It incorporates a 2,4 GHz radio system and an Arm Cortex-MO+ processor (CPU2). The embedded system features MOX-type chemical gas sensors to pick up and measure Volatile Organic Compounds (VOCs), CO2 concentrations, and the Air Quality Index (AQI) that surrounds the user. The pendant is connected to a smartphone via Bluetooth using an Android® compatible app and the data received from the device can be viewed in different ways in real-time. The energy source is provided by a 300 mA battery that offers several days of autonomy and ensures continued use in several scenarios.

Moreover, the app not only allows the real-time visualization of the environmental data but also offers advanced analysis capabilities such as interactive graphics and the comparison of historical data. The users can personalize the alerts to receive notifications when the levels of certain gases or pollutants exceed a defined threshold. This way, it ensures continued protection against long-term exposure to dangerous environments.

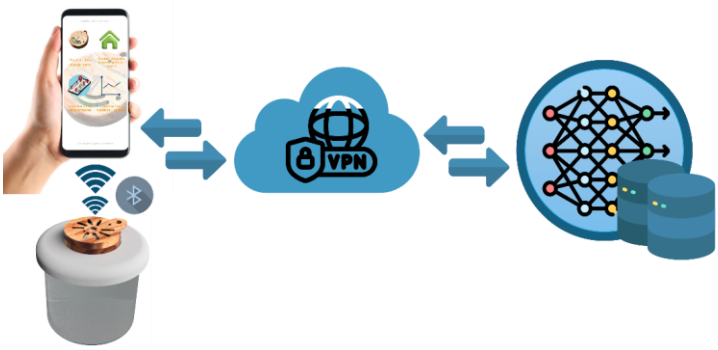

Figure 2: IoT Data from App to Cloud Neuronal Network via Secure VPN

This device can be trained to recognize smells in some applications such as food monitoring, detection of chemical biomarker gases in breath, and also personal air quality monitoring system. The app calculates automatically the characteristic values of a substance when it is measured and sends them to a web server as entrance data for a trained model based on neural networks. The server response is received by the application and shown to the user to indicate its type, in addition to an audio indication of the type of substance.

Thanks to the automatic calculation of the characteristic value and the web server, the type of substance can be obtained accurately in real-time. Another remarkable feature is the ability to share data with third parties safely. The anonymous data can be used by public health or environmental organizations to carry out pollution studies in specific areas. This kind of interaction encourages the collaboration between users and allows the creation of a distributed network of environmental monitoring stations worldwide, where each pendant acts as a node contributing with valuable data to the community.

SCOUT3 CASE STUDY: NESPRESSO CAPSULE SIMILARITY PROFILING

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The Goal of Volatile AI

Ingredient chemical profiling for quality control is a time consuming and highly complex task requiring professional chemists. At Volatile AI our goal is to create a solution for field and on-site chemical profiling without going to the analytical lab.

Coffee Quality Control Today

For roasted coffee monitoring today, several lab methods are used. Robusta and arabica blends can be tested using nuclear magnetic resonance (NMR), while gas chromatography – mass spectrometer (GC-MS) can be used for off-note control and in some cases for origin tracing. Meanwhile the final blend flavour is controlled by the master blender or the taster panel.

A lab analysis using GC-MS or NMR takes around 30-60 min of running plus the sample preparation and warm-up time. When accounting for the manual interpretation of the acquired peaks, the whole lab process can run into several hours to generate an insight for the business. Such complexity results in fewer screening points. Additionally, shipping samples to the lab increases CO2 emissions incurred in transport.

Volatile AI's Scout3 Testing

Scout3 can be tuned for multiple applications in coffee: arabica / robusta blend ratio control, washed / natural preparation method control and blend similarity scoring.

The sample analysis steps are the following:

1. Once the system is started, button is pressed on the touchscreen to trigger sampling warm up (takes up to 15 minutes).
2. In the meantime, 2mg of ground roasted coffee beans or brewed room temperature coffee are added to the sample vial.
3. The sample vial is manually sealed using a threaded cap.
4. Once the system and sample are ready, press the touchscreen button to trigger sampling.
5. Coffee samples take 5-15 minutes to get the full result.
6. The results are displayed on the screen. In the "advanced" software mode, the user can see the full lab like chromatogram of the chemical composition signal. In the "quick" software mode, only the final answer is shown. For example: "90% arabica".

Nespresso Coffee Pod Similarity Profiling

We recently did a study with brewed Nespresso Company capsules, trying to identify similaries between different capsule flavours. The approach involved testing Ristretto, Ristretto Decaf, Arpeggio, India, Ethiopia, Capriccio, Volluto, Volluto Decaf.

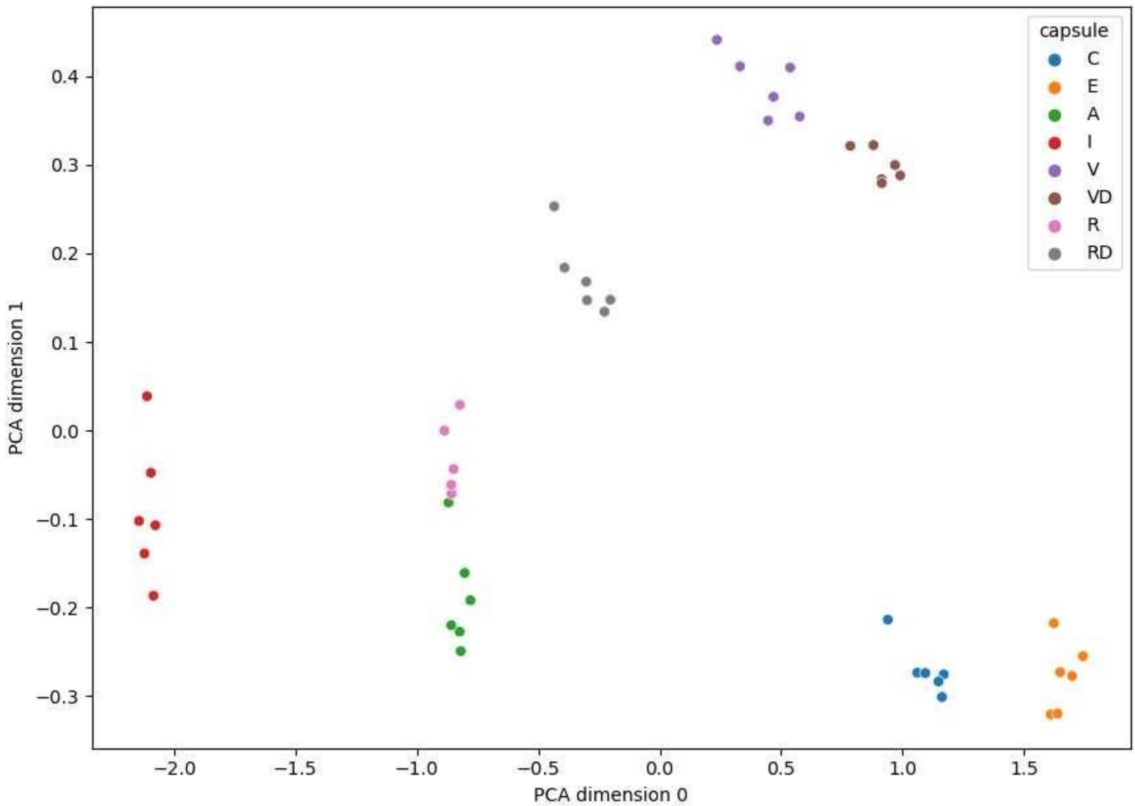
In parallel, the same capsules were tested using a GC-based benchtop electronic nose from AlphaMOS, called Heracles, by the Correltech Laboratory of ADEXGO Kft., Hungary.

In Scout3, the capsules were brewed using the Nespresso Mini coffee machine achieving 40ml of liquid. The brewed coffee was cooled in the fridge to 3°C and 1ml was transferred to the sampling vial. The sampling vial was incubated to 40C and then samples. The gas chromatography column was maintained at 25°C.

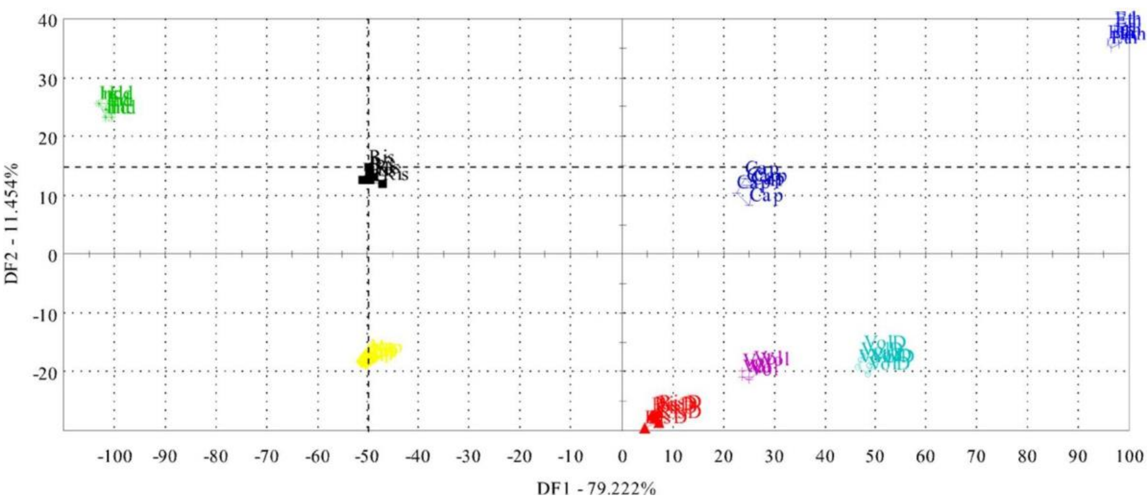
In Heracles, the capsules were brewed using the Nespresso Citiz coffee machine achieving 40ml of liquid. After cooling down, 1 mL of each sample was pipetted into 20 mL headspace vials. Vials were sealed with a magnetic cup having a PTFE-silicon septum. A needle and a syringe was used to take 5 mL headspace sample after an incubation at 40°C for 3 minutes, and the headspace sample was injected into the H2 flow to the chromatography column, heating the chromatography column up to 250°C.

The final results were very similar between both instruments, showing smell and flavour similarities between: Volluto and Volluto Decaf; Ristretto and Arpeggio, while India and Ethiopia were at the opposite ends of the flavour map based on principal component analysis (PCA) results.

It is important to note that Scout3 does not require special gas cylinders for carrier gas and can be transported around and set up in 15 minutes for sampling in 2 clicks. Meanwhile, it is able to achieve similarity scores of a lab instrument.



Scout3 Nespresso pod similarity profiling results (Red = India; Pink = Ristretto; Green = Arpeggio; Grey = Ristretto Decaf; Purple = Volluto; Brown = Volluto Decaf; Blue =Capriccio; Orange = Ethiopia).



AlphaMOS Heracles Nespresso pod similarity profiling results (Green = India; Black = Ristretto; Yellow = Arpeggio; Red = Ristretto Decaf; Purple = Volluto; Teal = Volluto Decaf; Blue1 =Capriccio; Blue2 = Ethiopia)

NEOSE™: HANDHELD ENOSE DEVICE BASED ON 64 GAS SENSORS ARRAY INTEGRATED IN BIO-FUNCTIONALIZED SILICON PHOTONIC CHIP.

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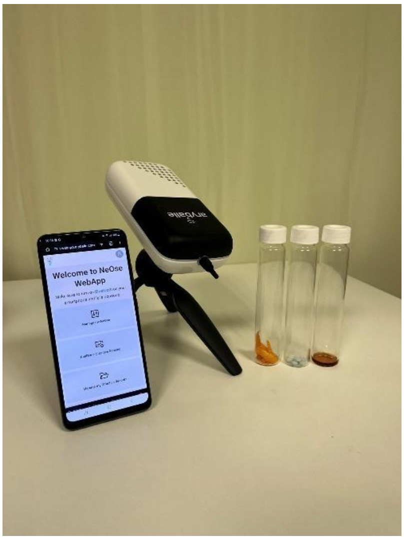
Machine olfaction mimic the olfactory detection system by using large array of differentiated gas sensor. Aryballe have developed a fully integrated array of 64 differentiated gas sensor. This sensor is embedded in a friendly-usable light and autonomous device, connected to a universally compatible web application. First generic sensing can provide absolute objective information of balanced chemical composition of detected volatile molecules, which can be related to odors.

Easy customizable relative analysis can be configured through learning of expected or unexpected odor context.



Left: NeOse device and a smartphone – Right: screenshot of dynamic sensogram, automatic signature computation and classification within learned database.

The demonstration will present:

- The fast and sensitive absolute response of device face to diverse volatile molecules sources.
- Fast and friendly process to learn and recognize new odor.

Based in Grenoble, France, Aryballe develops and manufactures bio-inspired “digital nose” sensors enabling groundbreaking applications in the food, cosmetics and automotive industries. Founded in 2014, it released its first product, the digital nose NeOse Pro in early 2018 and a technologically upgraded version in 2021. Early 2025, a fully portable version of NeOse will be commercially released. NeOse is used for quality control in the cosmetic industry, new flavors development in the food & beverage industry, or materials quality monitoring in the automotive industry.

OLFACTORY INTERACTION TOOLKIT DEMO

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Introduction: Olfactory interaction has immense potential to enhance multisensory experiences across various fields but is hindered by challenges like complex scent delivery systems and limited accessible tools. This demo presents two advancements from our ongoing research: a multi-functional odor delivery driver module and a sorbent-tube-based scent capture prototype, designed to simplify development processes and enable versatile applications.

Materials & Methods: The multi-functional odor delivery driver module (Fig.1) is a compact 3×3 cm device supporting multiple odor delivery components, including fans, heaters, air pumps, piezoelectric pumps, and micro-porous atomizers. Compatible with Arduino, ESP32, and Raspberry Pi, it includes a control evaluation board and PC-based control software for seamless operation. The second tool, a sorbent-tube-based scent capture prototype (Fig.2), refines the "smell camera" concept by replacing bulky gas bag storage with compact, reusable sorbent tubes, improving portability, usability and multi-scent capture and playback.

Results: Preliminary testing indicates that the driver module simplifies prototyping and supports diverse scent delivery methods. The sorbent-tube scent capture prototype enhances functionality, enabling reliable multi-scent storage in a compact form. Together, these tools represent practical advancements in olfactory interaction design.

Conclusion: The demo showcases how accessible and versatile olfactory interaction tools can empower researchers to develop innovative applications. Combining modularity, compactness, and multi-platform compatibility, these tools offer practical solutions to facilitate the adoption and evolution of olfactory interfaces in HCI.

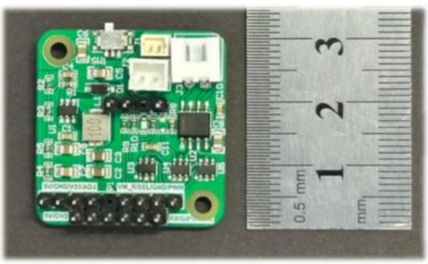

Fig.1 Multi-functional Odor delivery driver module.

Fig.2 The new scent capture prototype.

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BRAIN-COMPUTER INTERFACE-BASED IN VIVO BIOELECTRONIC NOSE

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Humans perceive the world through five senses, of which olfaction is the oldest evolutionary sense that enables the detection of chemicals in the external environment. Recent progress in bioinspired electronics has boosted the development of artificial sensory systems.

Here, we propose an olfactory brain-computer interface by integrating living mammals with implantable flexible neural electrodes, to employ the outstanding properties of mammalian olfactory system. The initial event of olfactory perception occurs in the olfactory epithelium (OE) inside the nasal cavity, which is the peripheral organ for the sense of smell. The olfactory bulb (OB) is the first relay station of the central olfactory system. It receives input from OE and sends output to the olfactory cortex. Under different odor stimuli, olfactory information encoding neural activities in OE and OB were simultaneously recorded using flexible neural electrodes. The recorded field potential signals were preprocessed and feature extracted, including time-domain and frequency-domain features. Then, traditional machine learning methods based on statistical theory, such as Support Vector Machine (SVM), k-Nearest Neighbors (k-NN), Linear Discriminant Analysis (LDA), and Decision Tree (DT), were employed for decoding and classification of these signals. Results showed that the linear support vector machine had the best classification performance among the traditional machine learning algorithms, with a maximum accuracy of 80%. Next, odor classification was achieved through automatic feature extraction using Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) network in deep learning. Finally, a model-agnostic meta-learning approach was used to train an ensemble classifier that combined the outputs of SVM, CNN, and LSTM, achieving a classification accuracy of 90% for recognizing and classifying different odor responses.

This study demonstrated, the chronic and stable electrophysiological recording of the central olfactory system using flexible electrodes, successful odor classification based on recorded electrical signals, and improved classification accuracy using ensemble learning. Overall, this approach provides a novel neural interface for olfactory biosensing and cognitive processing.

DEMO: OLFACTORY TEST WITH SNIFFING STICKS

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Olfactory dysfunction is a common disorder that affects approximately 22 % of the general population [1]. Olfactory disorders such as anosmia (total loss of smell) or hyposmia (partial loss) can negatively affect the quality of life causing problems identifying spoiled food, problems identifying poor body hygiene, safety issues, and depression among others [2]. For that reason, there is a need to offer patients reliable and precise methods to assess different olfactory disorders. One of the most frequent tests used is the "Sniffin Sticks"[3]. This test consists of different pen-like odor-dispensing devices filled with liquid odorants to test the olfactory capabilities of the patients. Different studies have proven that the Sniffin sticks are appropriate for the olfactory screening of different patients and they are suitable for clinical practice [4,5].

In this demo, an olfactory test with sniffing sticks is performed. The tests are made with the Odofin Sniffin' Sticks Screening 12 test from Burghart Messtechnik (Holm, Germany). The kit contains a set of 12 different odor sticks, each one is impregned with different substances to evaluate the olfactory capabilities of the patient.

The test is performed as it is shown in Figure 1a. Firstly, the patient takes a choice card corresponding to one odor stick, after that the patient must hold the stick 2cm centered in front of both nostrils and it is asked to smell for 3-4 seconds. Once the patient has sniffed the aroma is asked to choose a term on the choice card and the answer is marked on the identification sheet. This process is repeated for each stick with a minimal pause of 30 seconds to avoid interferences between aromas. Once the patient has sniffed all the sticks the answer template is checked. The number of correct answers are added up and compared with normative values Figure 1b.

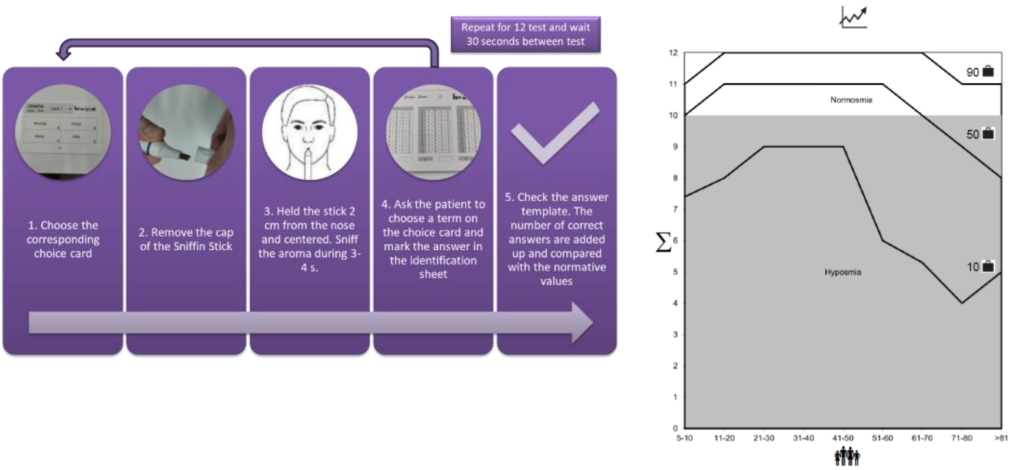

Figure 1. Test procedure. (a) Test steps. (b) Normative values.

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8th Annual Meeting of

Digital Olfaction Society

Abstracts for Poster Presentations

By Alphabetical Order

DEVELOPMENT OF AN ELECTRONIC NOSE-BASED COFFEE FERMENTATION MONITORING SYSTEM

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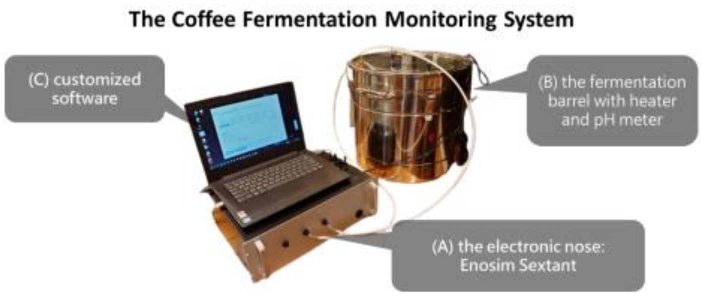
Introduction: The coffee fermentation process is vital for its final flavor. Fermentation time and temperature significantly impact the beans' chemical changes, making precise control essential to prevent over-fermentation and ensure quality. This study uses Taiwanese coffee beans and fermentation barrels for controlled experiments, with data collected via an electronic nose (e-nose). The data helps experts determine optimal fermentation timing, preserving flavor and avoiding over-fermentation.

Material & Methods: The system is composed of three integrated components: (A) the Enosim Sextant electronic nose [1-2], a high- sensitivity device capable of multi-dimensional analysis of volatile organic compounds (VOCs) and generating aroma profile curves to monitor fermentation trends; (B) a fermentation barrel with a heater and a specially designed gas flow ensures stable internal airflow and enables simultaneous monitoring of VOCs and acidity. A pH sensor in the barrel minimizes external contamination, tracks changes in acidity—an essential indicator of fermentation progression—and combines its data with eNose readings for multivariate analysis; and (C) customized software for automated workflow control, synchronized data acquisition, real-time visualization of aroma and pH trends, and advanced analysis, reducing manual intervention and improving data accuracy and efficiency.



Results: We used coffee beans from Mawudu in Hsinchu to monitor and record the fermentation process over three days. The experiment allowed us to observe changes during fermentation and, with expert olfactory senses, identify and classify the different fermentation stages.

Conclusion: Looking ahead, we plan to optimize experimental workflows based on this system to collect more comprehensive data and collaborate with more farmers.

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EXPLORATION INTO THE VIBRATIONAL THEORY OF OLFACTION BY ELECTRON TUNNELING SPECTROSCOPY

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Introduction: Our sense of smell shapes behavior, enabling judgments based on minute molecule concentrations[1]. Losing olfaction, evident with viruses like COVID-19, highlights its profound impact. Olfaction's mechanism remains incompletely understood and controversial [2,3] despite extensive research[4,5]. We aim to investigate the quantum mechanics-based model called the Vibrational Theory of Olfaction. According to this theory, the recognition of odors involves quantum mechanical inelastic tunneling of electrons through receptors bound to an odorant molecule [6].

Material & Methods: Using a Scanning tunneling microscope, we measured tunneling current versus bias across a gold surface in the presence and absence of an odorant at ambient temperature and pressure conditions. We studied different odorants: octanal(C8H18O), and nonanoic acid(C9H18O2). We also studied 1-Undecanethiol(C11H24S) self-assembled monolayers.

Results: Our measurements displayed a consistent tunneling current profile, with no significant variations associated with the presence of odorant molecules at the current resolution and noise levels.

Conclusion: These findings serve as a constructive foundation, paving the way for future investigations into the effects of low pressure (vacuum) and low temperature on the sensitivity of the tunneling current to the presence of odorant molecules when the noise level is significantly reduced.

Acknowledgment: This work was supported by a National Science Foundation (USA) grant MCB 2105612.

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Duke University

EXPLORATION INTO THE VIBRATIONAL THEORY OF OLFACTION BY ELECTRON TUNNELING SPECTROSCOPY

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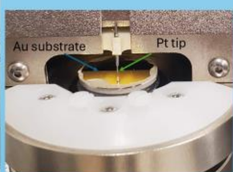
Introduction: Our sense of smell shapes behavior, enabling judgments based on minute molecule concentrations[1]. Losing olfaction, evident with viruses like COVID-19, highlights its profound impact. Olfaction's mechanism remains incompletely understood and controversial[2,3] despite extensive research[4,5]. We aim to investigate the quantum mechanics-based model called the Vibrational Theory of Olfaction. According to this theory, the recognition of odors involves quantum mechanical inelastic tunneling of electrons through receptors bound to an odorant molecule[6].

Material & Methods: Using a Scanning tunneling microscope, we measured tunneling current versus bias across a gold surface in the presence and absence of an odorant at ambient temperature and pressure conditions. We studied different odorants: octanal(C8H18O), and nonanoic acid(C9H18O2). We also studied 1-Undecanethiol(C11H24S) self-assembled monolayers.

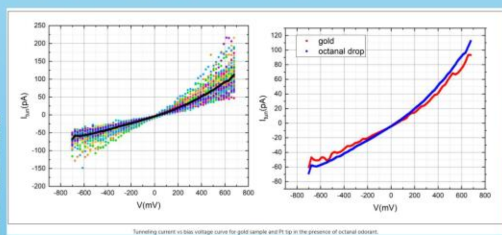
Main Results: Our measurements displayed a consistent tunneling current profile, with no significant variations associated with the presence of odorant molecules at the current resolution and noise levels.

Conclusion: These findings serve as a constructive foundation, paving the way for future investigations into the effects of low pressure (vacuum) and low temperature on the sensitivity of the tunneling current to the presence of odorant molecules when the noise level is significantly reduced

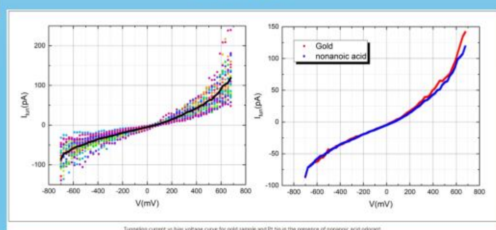
Scanning tunneling microscopy STM-based platform to investigate the putative interaction between tunneling electrons and odorants. Our STM vibration-isolation system is based on Dr. Dan Berard's design.



STM Head (Bruker)



Octanal ($C_8H_{16}O$)



Nonanoic acid ($C_9H_{18}O_2$)

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DIGITALIZED RECORDING OF OLFACTORY RESPONSES IN THE PROGRESSION OF ALZHEIMER'S DISEASES

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Introduction: Alzheimer's disease (AD) is a neurodegenerative disorder where early diagnosis is critical for effective intervention. Alongside cognitive impairment, approximately 90% of AD patients experience a decline of olfactory abilities, including difficulties with olfactory recognition and identification [1]. This study investigates the use of non-invasive olfactory bulb recordings to assess neural responses to odors in cognitively normal individuals (n=14), mild cognitive impairment (MCI) patients (n=39), and AD (n=18) patients. Importantly, digital recordings distinguished between early and late MCI stages as well as Normal and AD, which traditional smell tests could not achieve.

Material & Methods: A total of 71 individuals were initially enrolled in the study, based on the the research criteria proposed by the National Institute on Aging–Alzheimer's Association (NIA-AA, 2011) workgroups. Neuropsychological assessments were performed using a standardized neuropsychological battery called the Seoul Neuropsychological Screening Battery II (SNSB-II). All participants underwent a structural MRI scan. Brain DTI were acquired using a 3.0-T Achieva MRI system (Philips Medical Systems, Best, the Netherlands). Olfactory functions were assessed using the Brief Smell Identification Test (B-SIT) and responses were recorded using a six-channel active electrode EEG system (Cyton, OpenBCI, US), with data collected and digitized at a sampling rate of 512 Hz. All statistical analyses were conducted using MATLAB (version 2023b), utilizing the Signal Processing and FieldTrip toolboxes.

Results: An odor event-related synchronization (OERS) was observed in the beta (13-30 Hz) and gamma bands (30–100 Hz) approximately 200–550 ms post-stimulus [2]. In the normal group, odor-responsive signals appeared within 0.5 seconds after odor exposure. In contrast, AD patients exhibited no detectable gamma synchronization during these temporal and frequency intervals. The power of the gamma band gradually decreases, and the reaction time is delayed as the disease progresses from early to late stages.

Support Vector Machine regression achieved 88% accuracy in predicting AD, with significant correlations to neuropsychological assessments (SNSB-II).

Conclusion: When compared electrical signals from the olfactory bulb across all four groups, we observed a decrease in gamma band power and delayed responses to odor exposure. Moreover, although there was a significant reduction in total power between normal and AD subjects, no significant decrease in total power was found between the normal and MCI (early and late) groups, or between the early and late MCI groups. These results suggest a gradual delay in gamma band synchronization, finally leading to a complete loss of olfactory response.These findings suggest that olfactory bulb recordings could serve as a valuable tool for early diagnosis and monitoring of AD.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Ministry of Science and ICT (MIST) of the Korean government (RS-2023-00302751).

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Digital Recording of Olfactory Responses in Alzheimer's Disease Progression

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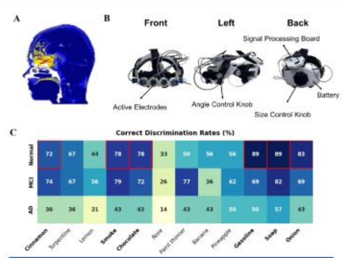
Abstract

An early diagnosis of Alzheimer's disease (AD), a neurodegenerative disorder, is critical for effective intervention. In addition to cognitive impairment, **approximately 90% of AD patients experience a decline in olfactory ability**, including difficulties in olfactory recognition and identification. This study investigates the use of **non-invasive olfactory bulb (OB) recordings** to assess neural responses to odors in cognitively normal individuals (n = 14), patients with mild cognitive impairment (MCI) (n = 39), and patients with AD (n = 18). In contrast to normal individuals, AD patients exhibit reduced gamma band power and delayed response to odors. Notably, digital recordings distinguished between early and late MCI stages, a distinction that traditional smell tests fail to achieve. Support vector machine (SVM) regression **achieved 88% accuracy in classifying those patient groups**, with significant correlations with neuropsychological assessments and medical images such as diffusion tensor image (DTI) and magnetic resonance image (MRI). The power of the gamma band gradually decreased, and reaction time was delayed as the disease progressed from early to late stages. This was confirmed across four stages, from normal to AD, including early and MCI. These findings suggest that **OB recordings can serve as a valuable tool for early diagnosis and tracking the progression of AD.**

Introduction

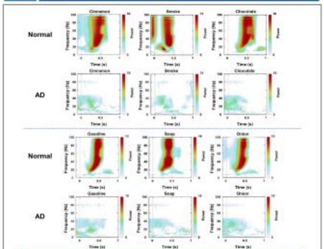
Digital olfactory testing was conducted alongside several traditional methods for AD diagnosis, including medical imaging techniques such as **MRI, DTI, and amyloid-PET**, as well as **neurobehavioral assessments** such as SNSB and MMSE, in addition to behavioral olfactory evaluations, UPSIT. In conventional approaches, various test results are synthesized to make a diagnosis by a skilled neurosurgeon. In contrast, the **method proposed in this paper** suggests the potential for early diagnosis of AD by **measuring odorant-mediated olfactory responses of the olfactory bulb**, in reference to traditional test results.

1 How and What should we Record a Digital Olfactory Signal?



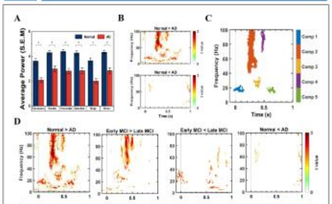
Six electrodes were attached to positions capable of measuring OB responses for digital olfactory reaction testing. According to previous studies, AD patients reported an olfactory impairment when assessed using B-SIT, which includes 12 odors selected from UPSIT. Because **familiarity and responsiveness to certain odors may vary among ethnic groups**, we first selected six types of odors (**cinnamon, smoke, chocolate, gasoline, soap, and onion**) with a correct answer rate of 70% or more among healthy individuals from the 12 smells in the B-SIT. The correct answer rate for the six selected odors was significantly lower in **AD** patients (14), averaging **45%** ± 0.06 compared to **81%** ± 0.06 in **Normal** individuals (18).

2 Odorant-Mediated Olfactory Responses (Normal, AD)



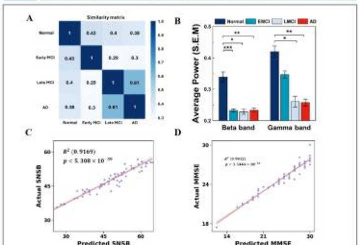
Spectrum of olfactory responses to the six selected odors in both healthy and AD patients. In the normal group, odor-responsive signals were observed within **0.6 s** after odor exposure, specifically in the beta and gamma frequency bands across six electrodes. Conversely, AD patients showed no detectable gamma synchronization at these temporal and frequency intervals, thereby affirming the ability to identify robust olfactory signals in the control group. **Gamma synchronization was observed in normal controls** following odor onset (indicated by the horizontal gray line at time 0) whereas no synchronization was detected in the AD group during the same period.

3 Olfactory Response Components Extraction



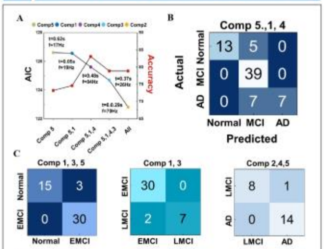
A. Averaged power change for odorant across 0–1 s interval, presented with standard error of the mean (s.e.m) for responses to six selected odorants. Statistical significance is indicated by * for $p < 0.05$.
B. T-map derived from 1000 Monte Carlo permutation tests, illustrating significant differences in **beta (13-30 Hz)** and **gamma (30-100 Hz)** bands between normal and AD groups.
C. Threshold t-maps indicating significant clusters (**$p < 0.05$, cluster size > 300**) that differentiate **olfactory response components** between normal and AD. Five distinct components were identified in the gamma and beta bands during early and late time points, with each component represented in a specific color.
D. Threshold t-maps, indicating a **gradual decrease in gamma synchronization and delayed reaction time** from normal to AD, significant in the beta and gamma bands.

4 Olfactory response predicts neurobehavior test outcomes



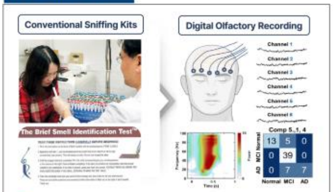
A. SSIM of olfactory response spectrograms. **High similarity was observed between the control and early MCI groups (SSIM = 0.43)** and between the **late MCI and AD groups (SSIM = 0.61).**
B. Averaged power change for odorants from each olfactory components, for responses to six selected odorants (Components 1, 3, and 5 exhibited beta band, while Components 2 and 4 belonged to gamma band).
C. Plot of the predicted versus actual **SNSB scores** using the mixed-logistic regression model, **regressing** the extracted key features from the **olfactory response** components as dependent variables.
D. Plot of predicted versus actual **MMSE scores** using the mixed logistic regression model

5 Olfactory response as a digitalized diagnosis tool



A. **Akaike information criteria** (AIC) for each olfactory response component. Accuracy of models with **stepwise adding components** shows **maximum accuracy** for the model includes components 5, 1, and 4.
B. **Confusion matrix of the SVM classifier model**: Out of 18 individuals in the normal group, 13 were classified correctly as normal, whereas 5 were misclassified as MCI. The classification was accurate for MCI groups. Among 14 individuals in the AD group, 7 were misclassified as MCI, achieving **83.09% accuracy**.
C. Cross tables of **distinguishing adjacent disease stages** (Normal-EMCI, EMCI-LMCI, and LMCI-AD) show true/false positive/negative values.

Conclusion



- In this study, although the conventional sniffing kit clearly distinguished between normal individuals and AD patients, the differences between normal and MCI subjects were not significant. We attempted to **digitize the measurement of the OB function** to differentiate cognitively normal individuals from early MCI, late MCI, and AD patients in a non-invasive manner. Accordingly, **we extracted discriminative components from olfactory spectrograms**, which successfully regressed against clinical AD diagnostic examinations, **demonstrating high levels of sensitivity, specificity, and accuracy.**
- These findings collectively support the potential clinical utility of this methodology as a novel diagnostic tool for early AD detection, offering an **objective and reproducible approach for quantifying olfactory bulb responses.**

Allfacto LAB : Navigate Olfactory Sensing and Electroceuticals

THE EVOLUTION OF THE NASAL TURBINALS IN LAURASIATHERIANS

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Mammals exhibit specialized nasal morphologies, including complex lamellar turbinals that increase the surface area of the nasal cavity. These structures provide scaffolds for olfactory cells, filter and thermoregulate air, and reabsorb moisture. Turbinal complexity varies among species; the lamellae branch and fold during growth, complicating homology studies. However, turbinal development is universal in mammals, forming from cartilage structures in the fetal nasal cavity in a rostral-to-caudal sequence. Hence, tracking turbinal developmental processes and comparing interspecies clarifies turbinal homology.

In this study, we performed micro-CT imaging after contrast agent staining on laurasiatherian mammals from fetuses to adults, including Eulipotyphla (Asian house shrews), Carnivora (cats), Perissodactyla (horses), Cetartiodactyla (pigs), Pholidota (short-tailed pangolins), and Chiroptera (fruit bats). By reconstructing three-dimensional nasal structures and analyzing their development, we clarified the homologies of each turbinal and examined evolutionary scenarios based on recent phylogenetic relationships. Our results suggest that the common ancestor of Laurasiatheria already possessed a large, multi-branched maxilloturbinal. Additionally, the number of ethmoturbinals increased in the common ancestor of carnivorans, perissodactylans, cetartiodactylans, and pholidotans but decreased in carnivorans. The study also indicates that the number of ethmoturbinal branches increased in the common ancestor of these groups.

VISUALIZATION OF MULTILAYERED SMELL STRUCTURE IN TOURISM VIA MOBILE SPECTROSCOPY

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Introduction: While traditional tourism studies often focus on visual and gustatory elements, olfactory experiences have been largely overlooked. However, the unique scents of a region reflect its distinct culture, nature, and lifestyle, offering tourists a profound and immersive experience. Current attempts, such as "scent maps," present flat and simplistic representations, failing to capture the multilayered and three-dimensional characteristics of a region's scent landscape. Furthermore, differences in olfactory perception between locals and tourists remain insufficiently understood. To create novel tourism experiences that integrate olfaction, this study delves into the definition of "unique local scents." We aim to visualize the complex and dynamic olfactory structures of a region, transcending simple object-derived scent sensing. By intersecting the olfactory experiences of locals and tourists, we explore methodologies that provide new discoveries for both groups. Using mobile spectroscopy, we focus on spatially fluid, layered scent structures, presenting a novel tourism experience where scents interact in space.

Material & Methods: This study focused on the scent experience of the sagaribana (barringtonia flowers) in Iriomote Island, Japan, and measured the multilayered molecular structure of the atmosphere in areas such as Sonai and the Urauchigawa River. A Field Asymmetric Ion Mobility Spectrometer (FAIMS), newly developed by RICOH, was employed for real-time, mobile measurement of gaseous compounds and odor molecules. FAIMS separates ionized gases and odor molecules using a special alternating electric field, generating spectra reflecting the molecular composition and concentration. Spectral data were collected by measuring the scent of sagaribana in bloom, followed by the atmospheric molecular composition in surrounding areas. This multilayered molecular data was used to visualize the scent experience within the tourism site.

Results: Spectral data obtained near the sagaribana flowers showed overlapping broad peaks of low signal intensity. The signals specifically originating from sagaribana were identified by bringing the FAIMS inlet probe closer to the flowers. Other broad signals were considered background components of the local atmosphere. Quantifying spectral changes as a function of distance from the flowers revealed that sagaribana-derived scent components diffused over a wide area, with standardized deviation below 1.5 σ even 100 meters away. Interestingly, although sagaribana's molecular components were widely present, our sensory perception of its scent was not always consistent, suggesting that molecular concentration and sensory experience do not simply correspond. Additionally, small broad signals, consistently present throughout the region, likely contribute subconsciously to the overall olfactory experience of the area.

Conclusion: By collecting such data on regional scent structures, we believe it can be applied to design of olfactory experiences in tourism.

Supported by: JSPS KAKENHI Grant Number JP24K03188 and JP21K00141.

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OLFACTORY-SOMATIC INTERACTION DESIGN FOR WEARABLE TECHNOLOGIES

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Digital olfaction offers technological possibilities for ambient scent output. Improvised dance interactions are crucial in revising design, informing hardware/software issues, power supply, garment robustness, and tailoring digital olfaction for body movement proficiency. AURA:MATON is a wireless olfactory wearable that diffuses scent by balancing biosignal input (brainwaves) with algorithmic perfumery output (1). Through electroencephalography (EEG) sensing, a dancer's brain electrical activity controls five scent vials on a custom-made leather harness lab to autonomously emit a choreography of scents. The objective was to leverage a) the quality of wearer bodily perception, performance, and presentation for olfactory wearables through somatic experience, and b) olfactory-somatic interaction design to inform data olfactation (2).

This critical design research inquiry is situated in the wider context of exploring multisensory wearables. I conducted olfactory design workshops and tested numerous prototypes in public presentations. Initial studies map the dynamics of olfactory output to reveal that scent oscillation is subtle and prone to changing odour environments—a limiting characteristic for olfactory display and, therefore, under-utilised.

Olfactory sensing input/output systems offer compelling, non-verbal communication channels for wearables developers. Extending olfactory-somatic design strategies will advance olfactory sensory input, control, and performance parameters. Precise and expressive scented data displays add sensory depth to experiences at the intersection of dance, wearables, technology and science.

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APPLICATION OF DIGITAL OLFATION TO THE TOMATO INDUSTRY: VEGGIE-NOSE PROJECT

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Introduction: The VEGGIe-NOSE project focuses on the application of an electronic nose (E-nose) for the tomato industry. Electronic noses are devices that mimic the human olfactory system using sensors to detect volatile organic compounds (VOCs). These compounds are key indicators of the freshness, ripeness, and quality of vegetables. Accurate detection of these compounds is crucial for optimizing harvest times, storage processes, and the quality of the final product. Additionally, the ability to detect contaminants and undesirable substances significantly contributes to food safety. The VEGGIe-NOSE prototype incorporates advanced sensors and technologies to identify and measure gases, providing an early warning system for issues such as spoilage, contamination, or storage conditions. The system uses metal oxide (MOX) sensors, optical and electrochemical sensors, and data processing techniques based on artificial intelligence [1]. The modularity of the prototype allows for the optimization of the sensor array for different applications, making it adaptable to various industrial needs [2].

Objectives of the project

- Sensor Development: Fine-tune materials and sensors for the detection of specific gases/VOCs. This includes optimizing sensors based on nanomaterials and integrating advanced technologies to improve selectivity and sensitivity.
- System Integration: Develop conditioning circuits and electronic control and measurement systems. The integration of communication modules such as Bluetooth and Wi-Fi allows for the creation of portable and efficient devices.
- Validation: Validate the prototype in the laboratory and in the field, and conduct tests with end users. This ensures that the system functions correctly under real conditions and meets user requirements.

Results: The expected results of the project are the development of a modular system that allows for the optimization of the sensor array for different applications. This includes the ability to detect a wide range of VOCs and contaminant gases at various stages of vegetable production, storage and processing and its use in diverse applications. Although initially focused on the food industry, the system has potential applications in environmental monitoring, the chemical industry, security, and health.

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ELECTRONIC NOSE USING BIOMIMETIC SPIKING NEURAL NETWORK FOR FAST ODOR SOURCE ESTIMATION

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Introduction: Accurate odor source localization is essential for applications like chemical leak detection and gas monitoring. Traditional methods often rely on single-sensor systems, which limit performance in dynamic environments.

Material & Methods: This study proposes using a biomimetic spiking neural network (SNN) with odor receptor neuron-inspired mechanisms for multi-sensor fusion in an electronic nose system. The SNN rapidly estimates odor source distance by processing data from a sensor array. The method was tested using a publicly available electronic nose dataset in a wind tunnel and compared with single-sensor approaches. Real-time performance was evaluated on a mobile robot platform.

Results: The SNN-based method achieved an average root mean square error (RMSE) of less than 0.1 m across different wind speeds, outperforming single-sensor methods in both accuracy and speed. Real-time testing on the robot platform showed an RMSE of 0.118 m with fast odor source estimation.

Conclusion: The proposed method significantly improves the speed and accuracy of odor source localization in the electronic nose system, showing strong potential for real-time applications in environmental monitoring and autonomous navigation.

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