Embodiment of Machine Olfaction: The Braitenberg Nose

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Abstract
There is an increasing attention towards machine olfaction and many studies show useful application through this type of technology, both for industry as well as for our lives. To further research in this area, from an interaction point of view, this paper presents the Braitenberg Nose, an artifact that explores how olfactory devices can be implemented in our lives through a tangible form. Users can present various smells to the nose that, based on the chemical composition and smell intensity, will show different movements through its nostrils and the sides of the nasal bridge.

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Interaction design, HCI research, Machine olfaction, Electronic nose, Gas sensors

ACM Classification Keywords
H.5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
In the past years, machine olfaction - the automated simulation of the sense of smell - is not only gaining attention in various industries like food analysis, environmental monitoring, agricultural industry and cosmetics industry [11], but research has also demonstrated meaningful applications in our lives as numerous systems are capable of identifying

simple or complex smells. For example, in the medical field, machine olfaction systems can be used to differentiate between head, neck and lung carcinoma, with high diagnostic accuracy [13]. More related to daily lives, indoor air quality monitoring systems with gas-sensors and dust monitors exists prevent indoor air pollution [1]. These systems could be used to control Sick Building Syndrome and Building Related Illnesses. Additionally, machine olfaction can be used for detecting the freshness of fish and meat [9], making it potentially useful for elderly with a reduced sense of smell.

Yet, until the end of the 20th century researchers did not label the olfactory dimension as an important interaction modality [4]. It was only recently that the sense of smell is considered important, as it is unique in influencing emotions and plays an important role in communication [4]. Hence, compared to visual and auditory communication, olfaction is rather under-explored in the field of Human-Computer Interaction (HCI), but can be a high potential paradigm for 'natural' interaction [4, 10].

To further explore how olfactory devices can be introduced into our lives as meaningful artifacts, this paper introduces The Braitenberg Nose. This artifact encourages users to interact with it through machine olfaction in a tangible form. Following a "Research through design" approach [15], the project was set to explore the implementation and embodiment of olfactory sensors. Through the computational composites framework [12], the form-giving of the artifact is explained.

Related work

Literature distinguishes between olfactory displays which evaporate smells and olfactory sensors which detect them. The former category includes several implemented systems to send olfactory information as ambient indicators. For example, 'inStink' is a system that provides a sense of presence between two spaces using scents: activities in a kitchen are augmented by evaporating smell to a remote room [6]. Additionally, 'Olfoto' shows how smell can be utilized to search within a digital photo collection by tagging photo's with smell to elicit memories [3].

To detect olfactory input, often Electronic Noses (e-nose) [5] are used, that comprises an array of different olfactory sensors (i.e. gas-sensors). Each sensor in the e-nose is sensitive to certain volatile molecules and respond to them in a different way. In such a manner, the output of the sensors will be different depending what volatile molecules are present, resulting in a signature of the detected smell. At the moment, most e-noses are applied in an engineering or industrial setting. For example, an application of the 'Mobile Nose', a remote controllable e-nose, is to localise a static odour source in a room [8, 7]. In the food industry it is showed that the commercial available 'Cyranose-320' e-nose has the potential to differentiate between different types of rice [14]. Next to that, there are several other commercial e-noses on the market [9], which are industry orientated. However, these e-noses are mostly packaged in a low-affordance, cuboid shape, not suitable for domestic settings.

The Braitenberg Nose falls into the category of olfactory detection, however, in contrast to the commercially available devices, our prototype is more designed from an interaction point of view [15], focusing on how humans can interact with this technology in a tangible form, i.e. embodying gas detection.

Concept & Implementation

Figure 1 shows the current prototype of The Braitenberg Nose. Users can present different smells to the nose, which

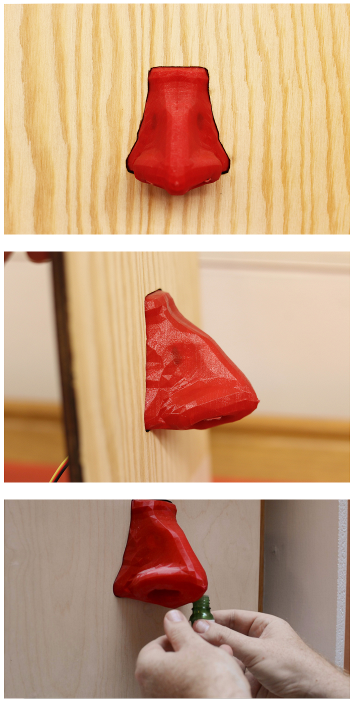

Figure 1: The Braitenberg Nose, in a frontview, sideview and while in use by a person.

will give various reactions in the form of breathing, sniffing and frowning. These movements are created by moving the nostrils and the sides of the nasal bridge up and down.

The artifact consists of three main parts: (i) a flexible, human-like nose, 3D printed with red Ninjaflex® filament; (ii) an e-nose for gas detection that is located behind the nose; and (iii) a system of strings, attached to the nose, controlled by three servo motors to animate its movements. The e-nose was made from three gas sensors (the MQ4, MQ6, and Grove) that are mainly sensitive to alcohol, methane, LPG molecules, as well as molecules that determine air quality. Additionally, smoke also influences the output of the sensors.

The amount of smells that can be detected is limited since the e-nose is made with only 3 gas sensors, constraining the amount of differences in each signature. To detect more variety of smells, a greater number of sensors is needed to have a wider range of volatile molecules responses. Currently, the best interaction with The Braitenberg Nose are achieved with alcohol-based substances, like alcoholic drinks, chili pastes and certain syrups.

During the implementation, one limitation of the gas sensors disturbed the interaction. The recovery time of gas sensors - the time it takes to return to the initial baseline - is overall quite long (about 120 seconds). This is inconvenient, as one cannot switch fast between different gases to create different reactions. Similar to the Mobile Nose [8], this problem was overcome by placing a fan at the back of the nose, blowing the air towards the sensors. The adopted solution allows the sensors to quickly desaturate and saturate, reducing the recovery time and improving the smell detection and interaction.

Approach

The concept was explored, tested and iterated according to the computational composite framework proposed by Vallgårda [12]. This framework supports form-giving practices for computational objects, consisting of three forms: the physical form, interaction gestalt, and temporal form. The physical form is the three-dimensional shape of the object and the reasoning of its appearance. The interaction gestalt is the link toward the user and what to do with the object. Lastly, the temporal form describes how the object behaves between different states, i.e. computational properties. This framework allowed us to characterize the qualities of the current implementation of machine olfaction more concretely. The following sections describe the three elements in more detail.

Physical Form

Different from visual and acoustic interaction, olfactory-based interaction and artifacts are uncommon for daily lives. Therefore, such an unfamiliar mode of interaction requires high affordance. Based on this affordance principle, the form of an abstract human nose was chosen to represent the olfactory function. The physical shape was first made in 3D-modeling software as a polygonal model and then realized with additive-manufacturing.

Interaction Gestalt

The user can present any smell to the nose and observe if one of the three sensors detects it. Depending on which sensors are activated, The Braitenberg Nose will move its nostrils or sides of the nasal bridge (or both) as a reaction to the presented smell. To determine the movement feedback of the interaction gestalt, an informal video study of human noses was carried out. Different movements of the nose were examined, including breathing (i.e. inhaling and exhaling), sniffing, and frowning. The ability to perform

Figure 2: The pictures show The Braitenberg Nose while performing a frowning movement.

these movements with the 3D printed nose were then implemented through a servo motor-based string system to achieve the desired responses.

Temporal Form

The interaction of the artifact is designed based on the computational properties of the gas sensors. Normally, a wide range of gas sensors is required in order to detect smell signatures that can be distinguished by either machine learning of pattern recognition [9, 5]. However, such technical requirements make the implementation of gas-sensors challenging. Instead, in The Braitenberg Nose, the computation was inspired by the Mobile Nose and Braitenberg vehicles [7, 2] to keep implementation comprehensible, but make the nose behave differently depending what smell is used in the interaction.

Braitenberg Vehicles are relative simple mobile machines that use direct sensor-motor connections to produce behavioral functions [2]. By varying these connections, various behaviours can be created. The Braitenberg Nose works with a similar concept in which each gas-sensor is coupled to a single servo motor, although programmatically through a microcontroller. This direct mapping enables the nose to make different movements depending on various smells. Additionally, the rotation of the servo motors is linked to the saturation level of the sensors, amplifying certain movements. To be noted, gas-sensors have a baseline which tends to drift over time - i.e. the output signal slowly changes over time, even if there is a steady input. This happens as, for example, the gas-composition in the room changes. To compensate for this, the output of the gas-sensor was determined from a baseline of each sensor, in order to keep the system stable.

Conclusion

The Braitenberg Nose enables users to interact with a physical artifact through machine olfaction. The nose communicates the activation and saturation of the internal gas-sensors through a tangible form by giving various reaction like breathing, sniffing and frowning. By presenting this artifact, we hope to inspire other interaction designers to experiment more with machine olfaction and to make it a practical and comprehensive interaction modality. In the future, devices like The Braitenberg Nose have to be put into context to see how users would work and respond to them in actual scenarios, and how machine olfaction can benefit their lives. Moreover, to ease the development of machine olfaction in domestic settings, e-noses with integrated calibration and computing could be valuable.

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Documentation

A video of The Braitenberg Nose giving reactions to various smells can be viewed at https://vimeo.com/260837181.

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