uSmell: A Gas Sensor System to Classify Odors in Natural, Uncontrolled Environments

Sen H. Hirano
University of California, Irvine
Department of Informatics
shirano@ics.uci.edu

Khai N. Truong
University of Toronto
Department of Computer Science
khai@cs.toronto.edu

Gillian R. Hayes
University of California, Irvine
Department of Informatics
gillianrh@ics.uci.edu

ABSTRACT
Smell can be used to infer quite a bit of context about environments. Previous research primarily has shown that gas sensors can be used to discriminate accurately between odors when used in testing chambers. However, potential real-world applications require these sensors to perform an analysis in uncontrolled environments, which can be challenging. In this poster, we present our gas sensor system, called uSmell, to address these challenges. This system has the potential to improve context-aware applications, such as lifelogging and assisted living.

Author Keywords Electronic nose, activity sensing.

ACM Classification Keywords H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms Experimentation, Measurement

INTRODUCTION AND BACKGROUND
Sensing user activities in an unobtrusive manner remains a difficult challenge [1]. For example, many approaches can be used to determine when someone used the toilet; these include the use of accelerometers or water flow sensors [5] and even vision- or audio-based solutions. However, it is hard to imagine widespread acceptance of vision- or audio-based solutions in bathrooms. Likewise, infrastructure-mediated sensing may not be able to identify specific details about toileting activities. Human noses, on the other hand, can infer these details because of its ability to identify and distinguish among a wide range of odors. Previous research has shown that gas sensors can be used to discriminate accurately between odors when used in testing chambers [2]. However, the challenges involved with unobtrusively sensing user activities in natural environments remains relatively unexplored. Although there has been some work using gas sensors worn on the body [3] or embedded into robots [6], our work has been focusing on challenges and prospects of affixing these sensors into the walls or ceiling.

In this poster, first we provide a brief description of the theory behind gas sensors. Then we present some of the challenges that are faced when creating a system for the home environment. Finally, we present our gas sensor system that will address some of these challenges.

UbiComp'12, September 5-8, 2012, Pittsburgh, USA.
ACM 978-1-4503-1224-0/12/09.

THEORY OF OPERATION
The gas sensors in products like carbon monoxide detectors are often special variable resistors, such as metal-oxide semiconductor (MOS) sensors, which leverage reactions that occur when sensor surface particles are exposed to these airborne molecules. These reactions cause a change in resistance of the surface, allowing these sensors to be used in analog circuits. MOS sensors can be designed to react to different molecules by varying qualities such as thickness, metal grain size, and the catalyst used to treat the metal. However, these variations often do not allow these sensors to react only to specific molecules, but rather the sensors are only sensitive to those molecules more than other molecules. To overcome this issue, gas sensors are often used in an array called an electronic nose, such that fingerprint can be obtained using all the sensors in the array, so now it can be better determined whether a signal was strong, or a molecule that the sensor was not sensitive to.

The rate at which an odor dilutes depends on the properties of the gas molecules. The weight of different gases can affect the rate at which it fills a room [8]. The rate of dilution, when coupled with the density of the gas, can affect the ability of a system from being able to identify an odor. Thus, the potency of that odor and the rate at which it dilutes are important features of an odor's fingerprint that can help to distinguish it from other ones.

CHALLENGES
These challenges, which are open issues that require further exploration, have been compiled through an analysis of the literature and through experience working with these sensors.

First, the unpredictable because the thermodynamics and air currents in a room are often in flux; however, to sensors, they can only "smell" what gases come in contact with them, causing non-linear and sometimes totally different signatures. Furthermore, a warm cup of coffee will release many more molecules, than a cold one, which presents issues with regards detection, identification, and localization. First, if the signal is not strong enough, it might not be significantly detectable over the "noise" of the room. Second, the smell signature changes depending on the temperature of the sample, requiring more extensive training and context to account for these differences.

Odor differentiation is another issue, which has multiple causes; among them are the similarity of some gases to another and "background" gases that are still in the air. First, some scents may only differ to one another in subtle ways. Typically, in laboratory style odor analysis only similar odors are differentiated among each other, such as identifying different kinds of beer [7] or small sets, because in a larger sample the differences between the odors can be lost to noise. Also, the degradation of samples over time is an issue, for example, something like milk will not always have the same odor (or scent) signature at different points in time, although this, allows for the milk's shelf life to be identified [4]. Additionally, there is little control over other odors that are already present in the room; however, as humans, we cannot always determine this due to our habituation to scents. Therefore, the clearing of a testing chamber has typically been performed between tests, but in home and normal environments, this is often impractical. Finally, in a process called sensor poisoning, some gases permanently bond to the surface of some gas sensors, which permanently changes that way that sensor responds to gases in the future.

USMELL SYSTEM

uSmell is a sensing system that records and classifies surrounding odors. As described earlier, MOS sensors are variable resistors, which react with the gas molecules found as a part of different odors. By incorporating this into a simple voltage dividers, an analog output voltage is obtained, which we connected to an Arduino so we can read each MOS sensor's sensitivity towards an odor on demand. We connected the Arduino to a laptop computer using a USB or Bluetooth connection. The laptop polls the Arduino once every second to read the sensors' values and stores these values for later analysis. Then we use these data to train a decision tree classifier found in the Weka machine learning toolkit.

We designed uSmell to be customizable in the sensors it uses and the resistors that form the voltage dividers. This helps when customizing the set of sensors in the platform, but also when swapping out sensors if they become poisoned or too old.

CONCLUSION AND FUTURE WORK

In this poster, we discuss some challenges to sensing odors in uncontrolled environments (*e.g.*, a house) and presented uSmell, an electronic nose system to operate in these environments and assist activities such as lifelogging or activity recognition. In future work, we will evaluate our system and explore potential applications, focusing on increasing accuracy and reliability in uncontrolled contexts. This work shows the potential of using gas sensors to infer context in an unobtrusive manner for future ubiquitous computing applications.

Figure 1. uSmell validation setup showing prototype sensors and a glass containing a liquid inside a sealed container.

REFERENCES

1. Beckmann, C., Consolvo, S. and LaMarca, A. Some Assembly Required: Supporting End-User Sensor Installation in Domestic Ubiquitous Computing Environments. *Proc. UbiComp 2004*, Springer (2004), 107-124.
2. Gardner, J. W. a. B., P.N. Electronic Noses. Principles and Applications. *Measurement Science and Technology*, 11, 7 (2000), 1087.
3. Kobayashi, Y., Terada, T. and Tsukamoto, M. A Context Aware System Based on Scent. *Proceedings of the 2011 15th Annual International Symposium on Wearable Computers 2011*. IEEE Computer Society (2011), 47-50.
4. Labreche, S., Bazzo, S., Cade, S. and Chanie, E. Shelf life determination by electronic nose: application to milk. *Sensors and Actuators B: Chemical*, 106, 1 (2005), 199-206.
5. Larson, E., Froehlich, J., Campbell, T., Haggerty, C., Atlas, L., Fogarty, J. and Patel, S. N. Disaggregated water sensing from a single, pressure-based sensor: An extended analysis of HydroSense using staged experiments. *Perv. Mob. Comput.*, 8, 1 (2012), 82-102.
6. Loutfi, A., Broxvall, M., Coradeschi, S. and Karlsson, L. Object recognition: A new application for smelling robots. *Robotics and Autonomous Systems*, 52, 4 (2005), 272-289.
7. Pornpanomchai, C. and Suthamsmai, N. Beer classification by electronic nose. *Proc. Wavelet Analysis and Pattern Recognition, 2008. ICWAPR '08. International Conference on 2008*, 333-338.
8. Roberts, P. J. W. a. W., D.R. Turbulent Diffusion. *In* Environmental Fluid Mechanics - Theories and Application. ASCE Press (2002), 7-45.